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EVALUATIONS OF EMISSIONS AND CONTROL TECHNOLOGIES IN THE GRAPHIC ARTS INDUSTRIES

PHASE I FINAL REPORT

GATF

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238

EVALUATIONS OF EMISSIONS AND CONTROL TECHNOLOGIES IN THE GRAPHIC ARTS INDUSTRIES

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FINAL TECHNICAL REPORT

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Office of Engineering Analysis
Process Control Engineering Division
Department of Health, Education and Welfare
Public Health Service
National Air Pollution Control Administration
5710 Wooster Pike
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FOREWORD

This report summarizes the studies made by the Graphic Arts Technical Foundation for the National Air Pollution Control Administration during the first phase of Contract No. CPA 22-69-72.

The work was performed by the Air Pollution Control Division of the Research Department of GATF and covers the contract period between April 28, 1969 and June 30, 1970.

This report is not intended to be a final one in this area inasmuch as work will continue in additional phases of the contract.

ACKNOWLEDGMENTS

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The Air Pollution Control Advisory Committee comprising thirty-seven (37) industry members (see Appendix A) is acknowledged for their technical review, assistance and support of this effort.

Dr. J. J. McGovern and Dr. Robert J. Reitz, Mellon Institute of Carnegie-Mellon University, Pittsburgh, Pennsylvania are acknowledged for their contribution to this study.

Mr. William H. Webber, Miss Naomi Berber, Mr. James Alm, Mr. Eric Harslem (former Foundation Research Director) and Mr. Kenneth Ball (former Project Manager) of the Graphic Arts Technical Foundation successfully coordinated the contractual and administrative procedures associated with this effort. Mr. David B. Crouse served as the principal consultant for the printing processes. The final report was typed by Mrs. Lenore Hyatt.

TABLE OF CONTENTS

SUMMARY 1

INTRODUCTION 3

1.0 PERSPECTIVE 5

2.0 SURVEY 17
2.1 Development of Questionnaire 17
2.2 Distribution of Questionnaire 17
2.3 Processing of Responses 20
2.4 Results 20
2.5 Emission Control Equipment 39

3.0 FIELD VISITS 41
3.1 Establishing a Geographical Priority 41
3.2 Discussion of Field Visit Tables 42
3.3 Field Observations 43

4.0 SAMPLING 47
4.1 Introduction 47
4.2 Methods of Sampling 47
4.3 Source Sampling Requirements 51
4.4 Measurements and Calculations 54
4.45 Measurement of Water Vapor 57
4.46 Measurement of Specific Gravity of Duct Gas 57
4.5 Industry Source Sampling Plan 58
4.51 Introduction 58
4.52 General Procedures 58
4.53 Planning a Source Test 58
4.54 Collection and Analysis 60
4.55 Efficiency of Air Pollution Control Equipment 60
4.56 Industry Emission Evaluation 60
4.57 Odor Measurement 61
4.58 Source Test Report 63
4.59 Summary 64

5.0 ANALYSIS 67
5.1 Introduction 67
5.2 Terminology 67
5.3 Methods of Analysis 67
5.4 Analytical Procedure to be Used by GATF 68
5.5 Review of Emission Measurement Instrumentation 69

Table of Contents cont'd.

5.51 Infrared Analyzer 69
5.52 Ultraviolet Analyzer 70
5.53 Gas Chromatography 70
5.54 Liquid Chromatography 72
5.55 Moisture Analyzers 72
5.6 Available Field Type Instrumentation 73
5.7 Existing Graphic Arts Industry Emission Data 75

6.0 SOLVENT FLOW CHARTS 79
6.1 Offset Lithography 82
6.2 Letterpress 86
6.3 Metal Decorating 92
6.4 Gravure or Intaglio Printing 108
6.5 Flexography 113
6.6 Screen Printing 118
6.7 Summary of Solvent Flow Charts 121
6.8 Fate of Solvents as Reported in Survey 128

7.0 CONTROL TECHNIQUES 133
7.1 Control by Modification of Processes 133
7.11 Process Control 133
7.12 Equipment Modification 134
7.2 Change of Process Material 138
7.3 Control by Incineration 146
7.31 Thermal Incineration 146
7.32 Heat Exchangers 147
7.33 BTU Content of Printing Press/Metal Decorating Effluents . 148
7.34 Catalytic Incineration 149
7.4 Control by Adsorption 150
7.41 Activated Carbon for Pollution Control 151
7.5 Other Means to Control 153
7.51 Scrubbing 153
7.52 Masking and Counteraction 154
7.53 Control of Pressroom Contamination 154
7.54 Dispersion Techniques 155
7.6 Economic Considerations 158
7.7 Adsorption Equipment 165

BIBLIOGRAPHY 169

APPENDIX A - Air Pollution Control Advisory Committee . . 179
APPENDIX B - Figures 185
APPENDIX C - Tables 203
APPENDIX D - Questionnaire 235

SUMMARY

A multi-faceted study was conducted under the terms of the contract entitled "Evaluations of Emissions and Control Technologies in the Graphic Arts Industries" to determine the nature of emission problems in the graphic arts and metal decorating industries. The scope of activity outlined was broad. Beginning with acquiring an initial perspective of the industry's involvement and its problems, the study progressed through several intermediate steps. By means of field visits and a survey of solvent and ink use, the industry's actual and potential problems were delineated and methods used for solving these were reviewed.

Available sampling techniques were critically reviewed with the intention of selecting a procedure capable of providing all data necessary to evaluate accurately a given source. An industry sampling plan was developed that will measure and attempt to characterize the emissions, according to the process, type of ink coating and substrate used. It is expected that an empirical correlation can be made between the nature of the effluent and the various process inputs.

Analytical procedures requisite to the chemical evaluation of effluents and sampling technique employed were examined and reviewed with personnel of the Physical Measurements Laboratory of Mellon Institute. It was concluded that although numerous and sophisticated techniques exist for the precise identification of gaseous compounds the less complex method of total hydrocarbon analysis would suffice for certain segments of the industry.

Solvent flow charts for the basic printing processes and modifications thereof were utilized to indicate the process variables in terms of inputs and outputs. Assumptions as to ink type, ink rate coverage, sheet dimensions and press speed were included in these charts to describe the printing operations and upon which to base material and heat balance as well as emission calculations. Metal decorating flow diagrams also included the variables of coating thickness and solvent content as well as quantity retained in the product. Solvent consumption data and assumed levels of operation variables were used to calculate emission rates for several processes.

In reviewing the solvent flow charts and related tables, it can be concluded that significant emissions can be expected from web printing (letterpress and lithography using heatset inks), metal

decorating, gravure and flexography. Accordingly, additional contract work will be program oriented, at least initially to lithography (specifically the web-offset operation using heatset ink) and metal decorating. These two processes are not amenable to effluent adsorption equipment and the relatively high drying temperatures used on these processes are more likely to create emissions containing partially oxidized organics. The potential, therefore, for atmospheric pollution problems appears greatest in these processes. The fact that the industry is large and has geographical distribution in the urban areas of the country and the recognized lack of emissions data due to a universally acceptable sampling and analysis procedure are further substantiated in this report relative to the process areas in question.

Further studies in web printing (namely, letterpress using heatset inks) gravure and flexography have been of necessity postponed for subsequent task work. Although appreciable quantities of solvent are involved in these processes (principally alcohols, esters and aliphatics), drying temperatures if elevated are sufficiently low that solvents are not subject to chemical modification. Also, use of aqueous systems in gravure and flexography is gradually increasing.

Control techniques were reviewed and presented in the light of information gained from field visits to equipment manufacturers and from those companies employing air pollution control equipment. There are three general approaches to the problem of controlling gaseous emissions from the printing and metal decorating industries: the first, the use of air pollution control equipment, the second, a change of process materials and the third is process modification.

Immediate requirement for control is being satisfied with control equipment, thermal and catalytic incineration, adsorption, scrubbing and other measures. All were considered from both a technological and economic review. Changes in process material (e. g., solventless or low-solvent inks) were reviewed to the extent possible as they represent a novel approach to solution of present air pollution problems. In addition, recent developments in radiative drying were discussed in order to focus attention on still another approach to reducing emissions.

INTRODUCTION

In order to conduct a systematic national investigation aimed at evaluating air pollution generated by the printing, publishing, newspaper and metal decorating industry, GATF proposed and obtained financial support for an emission study entitled "Evaluations of Emissions and Control Technologies in the Graphic Arts Industries," Contract No. CPA 22-69-72 with the National Air Pollution Control Administration, (NAPCA), CPE, Public Health Service, Department of Health, Education and Welfare. The contract awarded April 28, 1969 consisted of a ten consecutive month work period terminating on February 27, 1970.

Due to a manpower shortage and delay, the schedule for Phase I was reviewed and re-evaluated with NAPCA personnel in August 1969. GATF requested and obtained a four-month extension of the contract, from the original termination date of February 27, 1970 to a revised termination date of June 30, 1970.

The Phase I effort can be subdivided into nine task areas with Figure 1 (Appendix B) depicting the original and revised schedule by task efforts. Briefly, the program effort consisted of the following tasks:

1. Acquire an initial perspective for the study.
2. Gather data for screening methods of measuring emissions.
3. Develop survey forms.
4. Field visits.
5. Design/assemble measuring equipment, develop procedures.
6. Mail, follow-up and tabulate survey data.
7. Develop guidelines for evaluating emission control alternatives.
8. Develop an industry solvent flow chart.
9. Develop a source sampling plan.

The expected goals of the Phase I effort were (a) to gain a reliable perspective of the technical aspects of emission control by defining materials, processes, emissions and control technologies in five areas of the printing industry: lithography, letterpress, gravure, flexography, and metal decorating; and (b) to screen various methods of emission analyses to arrive at equipment and procedures sufficiently accurate, reliable and simple to effectively engage in subsequent activity such as effluent characterization, control technology capability, equipment evaluation, and emissions prediction by process (proposed Phase II). Information for (a) above would be accumulated by personal contacts, searching appropriate industry and government publications, and a formal mailed survey.

1.0 PERSPECTIVE

1.1 Perspective of the Industry

1.11 Structure

The printing and publishing industry ranks seventh in value added to the Gross National Product and eighth in employment. The industry in the United States is the world's largest and is composed of more than 40,000 establishments (1)*. However, the industry is recognized as the domain of the small businessman since approximately four of every five establishments employ fewer than 20 persons.

Commercial printing, those who print for the trade, is designated by the U. S. Department of Commerce Standard Industrial Classification system as SIC 2751, those using the letterpress, gravure, flexographic or screen process; and SIC 2752, those using the lithographic or offset process. These two classes include almost half of the establishments in all of SIC 27.

In the 1967 Census of Manufactures Preliminary Reports (2) (the most recent census data available), there were 18,930 commercial printing establishments: 12,100 in 2751 and 6,830 in 2752. However, only 11.8% of the former and 24.1% of the latter reported having 20 or more employees.

Although additional 1967 statistics on distribution according to size are not yet available, a 1968 paper on trends in the industry (3) characterized the number and size of establishments for the period 1963-67 using 1958-63 statistics as the basis for comparison. Since printing is a relatively stable industry, changes occur slowly and trends, once established, tend to continue. Therefore 1963-67 data may be considered to be as applicable to the present as the 1958-63 statistics were to the 1963-67 period.

SIC 2751. In 1963 small establishments (less than 50 employees) represented about 95% of the total and accounted for 39% of the value of shipments. Those with fewer than 20 employees (88% of total) accounted for 25% of the shipments. Also, 49% of the dollar volume was realized by companies representing only 6.3% of the establishments. The total reported for 1967 (12,100) was almost identical to 1963 (12,109).

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*Bibliographic reference number

SIC 2752. In lithography, the number of small establishments in 1963 represented 93% of the total and accounted for 43% of the value of shipments; 47% had fewer than five employees and 80% fewer than 20. In addition, 57% of the dollar volume was realized by companies representing 7% of the establishments; 41% by less than 4%. During 1963-67 the total number of establishments remained essentially unchanged (6,822 to 6,820) and those with fewer than 20 employees increased approximately 6%.

Commercial printers, usually medium to large companies, extensively employ more than one process in the manufacture of printed products. Therefore, an establishment may be classified in 2752, since more than half of its activity is in lithography, and still derive a large portion of its income from letterpress. Any combination of processes is possible. The extent of multi-process facilities is illustrated in tabulations of results of the survey conducted, especially Tables 10 and 10a in Section 2.44.

In addition to commercial printing, other segments of the industry also classified in SIC 27 include newspaper publishing, book printing and publishing, periodicals publishing and printing, manifold business forms and typesetting. Publishers who do no printing and the typesetting industry are not included in subsequent discussions except when the entire industry is mentioned.

However, a substantial amount of printing is performed by industries which by major activity and/or definition are otherwise classified. Among these are segments of the diversified paper and packaging industries, especially converters. Metal decorating, an activity of the metal can industry, also falls in this category.

The metal can industry (4), SIC 3411, consists of over 100 companies (280 plants) producing steel or aluminum cans. The four largest account for 74% of production and the 20 largest companies account for 95%. Most are also active in other types of packaging.

Merger activity is strong throughout the printing and publishing industry. The diverse nature of the graphic arts, both in terms of products and firms, the need for diversification on the part of larger corporations, and the desirability of entering specialized printed product markets are important factors in this activity. In the five year period ending in 1967 (5), 284 companies in the printing and publishing industry merged. Book, periodical, and newspaper publishers accounted for 51% of the total and commercial printers 23%.

1.12 Geographic Distribution

Printing activity (all processes) is concentrated in the urban areas but also is scattered throughout the 50 states. There is hardly a county in the country without a newspaper or commercial printing plant. Over half of all commercial printing is performed in four states (6): New York, Illinois, Pennsylvania and California.

The major production areas for periodicals publishing are in the cities of New York, Philadelphia and Chicago (letterpress predominates). Book publishing is concentrated in the same cities as well as in Boston and Los Angeles. (The majority, 75%, of books and pamphlets are now printed by lithography.) Although New York, Chicago, Los Angeles and Philadelphia locate most of commercial printing, San Francisco, Cleveland, Boston, Cincinnati, Atlanta, Washington, D. C., Baltimore and St. Louis are also major centers.

Those segments of the paper and packaging industries which perform substantial amounts of in-plant printing are located primarily near the large market areas of the east and west coasts, the Great Lakes region, Pennsylvania and Texas (4). Package printing, on paper and plastic films, is done principally by flexography and gravure and metal decorating by lithography. Metal decorators are concentrated in the East North Central, the Pacific, and Middle Atlantic areas of the country (4).

Screen process printing is the smallest segment of commercial printing. Although fragmented, plants are generally located in large cities. In addition to textile printing, it is concerned with pressure-sensitive decalcomanias and labels, sign printing, advertising of all kinds, and a small portion of the glass and metal decorating, mostly of a specialty nature.

To the extent possible, geographical distribution of commercial printing by process is presented in Table 1 (Appendix C). The data contained therein, gathered almost entirely from government sources, should be considered as indicative rather than numerically precise, since printing, as one step in production, is performed extensively in other industries (Section 1.11). In gravure, virtually every substrate is used and activity is spread throughout many industries. Printing performed in-plant in the packaging industry represents a substantial portion of flexography's total, since almost all milk cartons and half of flexible packaging materials are printed by this process (7).

1.13 Economic Status

(For obvious reasons, data compiled during the planning stage and initial work period of the study have been adjusted to be as current as possible for this report.)

The printing and publishing industry, which comprises a total of 20 categories of industrial activity,realized industry shipments in 1969 in excess of $24 billion, a gain of $10 billion (60%) over 1960 and is expected to reach $25.7 billion in 1970 (1). During the period 1960-69, employment increased 20 percent and capital expenditures 126 percent.

As stated previously, the industry is recognized as the domain of the small businessman and is characterized by steady growth, stable employment, high wage rates and a large number of establishments. Economic performance during the 1960's closely paralleled the performances of the total economy and continued to represent 3 to 4% of the Gross National Product. Accordingly, Printing and Publishing ranks eighth in total employment and seventh in value added to GNP.

The variety of needs served by the printed product results in a demand constantly increasing because of population gains, school enrollment, income levels, and expanded business activity.

New technology, primarily innovations of the supplier and peripheral industries, has had a profound effect on the traditional concept of printing as a craft industry. Management has acknowledged the merit of accommodating tradition and the judicious use of technology to satisfy the market for individual printed products. In achieving this desired end, individual processes, formerly exclusive provinces, now share the market for certain products.

Financial growth experienced by the categories in the industry of major importance in this study during 1963-67 and estimated for 1967-70 are presented in Table 2 in Appendix C. Five categories in the industry experienced annual rates of growth greater than that of both the industry as a whole and the GNP (10): Book Printing, Gravure, Screen, Lithography, and Manifold Business Forms. Although the value of products printed by letterpress has been increasing, the rate of growth has been below that of lithography and estimates for 1967-70 indicate a 26% increase compared to 45% for lithography. Much of lithography's prosperity is attributed to the growth of web offset.

Web Offset. During the past ten years web (roll-fed) offset has matured with sales of over a billion dollars (8) and quality comparable to letterpress, gravure and sheet-fed offset, and at costs lower than all three. As a result, it is said to be now the fastest growing segment of the industry at 12% per year and is expected to continue for at least five years. (For three years prior to 1969 gravure experienced a 42% increase for an average annual increase of 14% (9).) The 1967 Census figures for the first time separate where applicable shipments of sheet-fed and web-fed offset: $449 million and $113 million, respectively (2b).

It has been predicted (8) that by 1978, 88% of the 1560 daily newspapers in the United States and all of the weeklies will be printed by web offset, although the bulk of web offset at present is used in newspapers of under 100,000 circulation (11). The process also is moving very aggressively in magazine publication and book printing, where approximately half of the books printed by lithography (75%) are done by web offset (12). Expected technological achievements in presses will allow the process to compete with gravure in the packaging field.

A serious disadvantage of web offset is paper waste, the greatest among all processes.

Letterpress. Although it has long been considered the printing industry's number one reproduction process, letterpress has been losing supporters at an alarming rate over a decade (13). Its annual rate of growth 1963-67 was only 1.9% while that of lithography was 10.1% (10). Once the giant of the industry with 62% of the commercial printing market in 1958 (14), letterpress in 1970 will have only 39% of the $8 billion total commercial printing market and lithography 52% (10). One of the most severe blows to letterpress prestige has been the invasion of web offset into the newspaper field. However, 93% of the nation's newspapers still print by letterpress (15).

The printer has recognized the advantages of other processes and, in many cases, has abandoned the traditional relief surface as the best way to print. An executive of a graphic arts management corporation (16) in an objective appraisal of the status of letterpress stated that letterpress printers were the major contributors to the growth of offset during the last quarter century because of the lack of concerted research.

Magazine and periodical printing continue to account for the bulk of letterpress shipments, followed by advertising, labels, catalogs and financial printing. Page flexibility for regional ads in national magazines is a distinct advantage of the process which also is the most economical for the growing business forms market.

Letterpress is one area in which small establishments may be in a more advantageous position than the large corporation engaged exclusively in this process. Without massive investments in capital equipment, a changeover to other technicques, equipment or processes may be more economically feasible (17).

Champions of the process insist, however, that it is not always necessary to switch to offset in order to keep abreast of the new technologies (18) and that the very qualities which made offset so effective are now being exploited on a widening scale for the revival and to the advantage of letterpress (16).

Since letterpress showed an estimated increase of 26% for the period 1967-70 (10), it continues to be a major printing process.

Lithography. The health of lithography has been stated partially in descriptions of Web Offset and Letterpress. In 1961 lithography held only 38% of the commercial printing market, but the estimate for 1970 is 52% (10). Its growth from 1963-67 was 45%, while "other commercial printing" was 22%. Typical of its growth is the fact that in 14 years (1954-1968), its dollar share of book printing (both sheet-fed and web-fed) rose from 24% to 75% at the expense of letterpress which has decreased to 25% (19).

In the opinion of at least one writer (20), the rapid growth of offset can be traced directly to the spectacular development of cold type composition. In a relatively short period of time, phototypesetting machines have been developed that set text-matter type at more than twice the speed of the fastest hot metal machines, as well as cathode ray tube composing machines which operate at speeds 50 to 100 times that of hot metal. Since offset is basically a photographic process, it can readily use any present and future electronic composition developments that may evolve.

Automated platemaking, cheaper and better plates, faster and better presses also have been instrumental in the comfortable position that lithography enjoys in the market.

Gravure. Gravure printing is concentrated in three general categories (9): (a) publications and advertising (newspaper, magazine preprints and supplements, magazines, catalogs, advertising, financial and legal forms, trading stamps); (b) packaging (folding cartons, flexible packaging such as cellophane and metallic foil, gift wrap, labels); and (c) specialties (floor and wall coverings, vinyl upholstery and clothing, decorated laminates for furniture surfaces, medicinal pellets and capsules, securities, sanitary tissues and health products). Essentially every type of substrate is employed.

Because gravure printing is performed in these widespread areas of industrial activity, government census statistics are considered by the industry to represent incomplete coverage and are evaluated as such. Accordingly, surveys conducted by the industry for industry interests reflect statistics as inclusive as possible. An industry survey (9) reported a total dollar value of gravure-printed products for 1968 of almost $2.2 billion, and $1.5 billion for 1965. Census figures (1967) reported value of receipts of only $407 million assigned to gravure. The 1963 Census was the first in which any figures were indicated for gravure as a separate industry (21).

Web offset's invasion of gravure's market is being challenged by new developments such as automatic color scanners, automated cylinder engraving and electrostatically-assisted ink transfer from engraved cylinders. Since gravure can reproduce illustrations with excellent color control, can be used on almost any substrate and, in certain products, be ingested, its position in the packaging field appears to be assured. The U. S. Department of Commerce estimates that a 30% increase will be realized by gravure for the period 1967-70 over 1963-67 (Table 2, Appendix C).

Flexography. Flexography is basically a letterpress (i.e., relief image) process using rubber printing plates and fast-drying low-viscosity inks which originally were based on aniline dyes as colorants. Thus, the process was known as "aniline printing" from 1890 (22) until 1952 when it was renamed through the effort of the Packaging Institute (23). Most flexographic inks are now colored with pigments as opposed to dyes.

Widely used in multicolor printing on a variety of substrates including flexible plastic films and aluminum foil, the process is associated with gravure in the converting and packaging industry. In fact, the two processes frequently are used in sequence so as to achieve certain qualities with economy. Since the flexible rubber plates used can cause image distrotion, the quality is not equal to gravure, but for economical and rapid printing of packaging materials, flexography is well-suited. Essentially 100% of milk cartons and multi-wall bags, 50% of the flexible packaging and 35% of gift wrap and business forms are printed by flexography (7). Its position in the packaging industry virtually assures its growth. Estimated receipts for 1970 will be 11% higher than in 1967, reported to be $304 million (Table 2, Appendix C). As in the gravure industry, flexographers believe much of their market is included in reports for other industries.

Screen Process. Although representing the smallest segment of the printed products market ($93.4 million, excluding textiles, in the 1967 census) screen printing showed extraordinary growth in the period 1963-67, and 1970 receipts are expected to reach $210 million, a 62% increase during 1967-70, based on $130 million estimated for 1967 (10). Much of this growth is due to the introduction of automatic screen printing machines. Probably more than half of the screen printing done is not mechanized. A survey of the industry conducted in 1966 (24) indicated that less than half of the printers had presses.

Also from that survey: sales in 1965 of $121 million were reported from the 475 (of 2700) printers who responded. A figure of $339 million was projected for all 2700 since returns came from firms with a wide spread of sales volumes and were well distributed geographically. Paper and cardboard signs, displays, posters and pressure-sensitive labels were named as the major products. Only 1.5% reported their major product to be metal signs. The average plant employed 15 persons (82% with less than 20); 52% had sales of less than $50,000, 11% between $50 and $100 thousand. Less than 2% realized a million dollars or more in sales.

A growing application not usually considered to be a part of commercial printing is the production of microcircuits.

Metal Decorating. The economy of metal decorating is dependent on the packaging and metals industries and is classified as a product of the metal can industry (SIC 3411). However, except for the coating step, it is a printing operation and is considered by both printers and metal decorators to be an important segment of the printing industry.

Because the planographic image plate and the rubber blanket of the offset press deposit ink on metal in a fashion far superior to any other process (25), lithography is the process used almost exclusively in decorating metal for use as containers. The value of products shipped in 1968 (4) was $3.5 billion with a projected increase, 1967-70, of 11%. By 1975, the total is expected to reach $5.4 billion.

1.2 Perspective of the Problem

To provide a foundation from which the study could commence, it was first necessary to determine the sources, character and degree of atmospheric pollution by the industry. An appreciation of the current problems was acquired in several ways.

A literature search conducted principally with trade publications and the Foundation's publication, "Graphic Arts Abstracts" furnished the means of identifying companies with air pollution experience whether acquired in control, abatement, or violation. Consultation with Foundation staff members having extensive experience in graphic arts, and examination of published trade association and Census Bureau figures characterizing the industry allowed a determination to be made regarding company size, printing process(es) involved, consumption of raw materials, dollar value of product, operating procedures and the like. Personal contact by visits to major companies employing the various printing processes and chosen according to the above considerations as well as geographical location, served to broaden the perspective acquired from published information and provide details regarding industry practices, means of measurement and/or treatment of emissions where possible, equipment in use and, to a limited extent, materials consumed and volume of product. Company anonymity was preserved throughout.

While acquiring an industry perspective and identifying those phases of printing activity currently involved in air pollution, data were being obtained to develop a questionnaire suitable for conducting a survey primarily of solvents and inks used during the previous year (1968). In addition to characterizing those phases of the industry already possible contributors to atmospheric pollution as defined by existing legislation, the purpose of the survey was to determine those areas susceptible to coming legislation as well as those considered to be free from concern.

In addition to these areas of activity, the acquisition of additional material to support the study also was initiated. Equipment and instrumentation catalogs representing comprehensive coverage in the field of emissions analysis, control and abatement were obtained and scanned as the initial step in establishing a selective compilation classified according to function and/or application. Files of legislation including copies of major laws (tax credits and incentives as well as restrictive) enacted at federal, state and local government levels were established. In order to facilitate certain tasks and to provide immediate assistance as a referral service furnishing a limited amount of technical assistance, pollution engineers and consultants, especially those with experience in the printing industry, were identified. Information relative to the latter qualification does not exist as such and was obtained either in conversation or as an incidental fact mentioned in publications and occasionally in promotional advertising.

In order to maintain current awareness, certain of the efforts initiated to acquire a perspective for the study were continued on a regular basis. Periodicals and journals (20 to 30) were reviewed regularly for pertinent material, and appropriate agencies were contacted as frequently as required to receive routinely copies of pollution laws passed and other published accounts of legislative activity.

1.21 Field Visits

The objectives of Phase I as outlined in the introduction were to gain a perspective of the air pollution problem facing the industry utilizing a planned investigation and developing suitable procedures for measuring emissions. A major source from which information was to be accumulated to meet these objectives was through personal contacts during field visits.

Area field trips to various geographical sections of the country were planned in order to complement the survey material and to accumulate information on existing methods of sampling and analysis in use throughout the country to measure and evaluate graphic arts industry emissions. In addition to printing and metal decorating plants, contacts included ink suppliers, dryer and air pollution control equipment manufacturers, engineering and laboratory firms, educational institutions, and local air pollution control agencies, all of which, to some extent, have experienced air pollution control problems related to the graphic arts industry.

The personal visits were intended to provide information as outlined below. Specific information was requested of printers and metal decorators as well as major suppliers to the industry.

A. Identify Printers and Metal Decorators as to:

1. Location
2. Process(es) and press equipment (including throughput rates)

3. Product(s); approximate quantities
4. Inks and solvents used for production; amounts consumed
5. Papers or printing surfaces used; amounts consumed
6. Drying equipment
    a. type, manufacturer, model
    b. air flows and temperatures
    c. fuel or heat consumption
    d. stack geometry
        (1) single or manifolded
        (2) cross-sectional area
        (3) height above roof
        (4) approximate running length
7. APC equipment (if any)
    a. type, manufacturer, model
    b. flows and temperatures
    c. fuel consumption
    d. method of performance validation if any and manufacturer's claims
    e. equipment, installation operational costs
8. Any available emissions data

B. Identify major ink and solvent suppliers as to:

1. Chemical composition of products insofar as possible; at least representative formulations of volatile components
2. Quantities supplied and major customers (geographical market and amounts to end users)
3. Solvent sources
4. APC associated data
    a. APC used in manufacture
    b. APC related modifications offered (exempt solvents)
    c. Analytical methods applicable to APC

C. Identify dryer equipment manufacturers as to:

1. Equipment in general use vs. printing process
    a. operational performance data (as listed in detail under "printers")
    b. costs
2. New or soon to be available equipment

D. Identify representative APC equipment manufacturers as to information similar to that listed under "C" above.

2.0 SURVEY

2.1 Development of Questionnaire

The source of effluent to the atmosphere from printing and metal decorating plants is primarily organic solvents contained in a wide variety of inks and varnishes used to manufacture the printed product. Accordingly, a survey was undertaken to generate information as to solvent use in the industry. The survey ultimately would characterize which phases of printing activity are involved in air pollution as defined by existing legislation, which areas are susceptible to new legislation and which areas are free from concern.

A questionnaire entitled "Survey of Solvents and Inks Used in the Printing Industry During 1968" was drafted by the GATF staff, reviewed by its Air Pollution Control Advisory Committee (printers, suppliers and trade organizations [Appendix A]) who offered extensive and valuable constructive criticism, and evaluated by the Process Control Engineering Division of NAPCA as a disinterested party before it was submitted for approval to the Bureau of the Budget. (A copy of the questionnaire appears in Appendix D.)

2.2 Distribution of the Questionnaire

a. Composition of the Mailing List. Selection of respondents was primarily through the use of the GATF and trade associations' membership lists with type of process(es) and relative size of company designated to some extent. Much of such information is common knowledge among GATF staff members. Trade periodicals which regularly cover stock market activity, annual gross and net earnings, Fortune Magazine's (May 1969) annual list of America's top 500 industrial corporations in terms of sales, and the like were consulted.

The assistance of trade associations (Gravure Technical Association, Flexographic Technical Association, Printing Industries of America (local and national sections), National Metal Decorators' Association, National Association of Photo-Lithographers, American Newspaper Publishers Association) was solicited regarding the use of membership rosters to augment that of GATF to prepare the mailing list of survey recipients.

Coverage by printing process was assured by a combination of personal knowledge and trade association membership. Newspapers

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which print daily by offset (rather than letterpress) were easily identified from annual trade publication sources. Lists of web offset installations to June 1969 were made available to us for the survey. Web offset represented a major potential source of organic effluents because of the heatset inks used. Therefore, web offset was covered as exhaustively as possible. (Since that time certain local and state regulations have caused concern in gravure also, and HEW has published criteria for hydrocarbons.)

Geographic coverage became almost automatic as the list was compiled. It was further insured, however, by including small firms in small cities and towns in the less densely populated areas of the country, who hold membership in one or more of the major trade organizations. Further reason for not excluding such companies is that merger activity in the industry is very high and many small companies are becoming subsidiaries of larger corporations. Thus, small operations can readily become a part of larger corporate activity.

The prime company contact, i.e., the person to whom the questionnaire was addressed was determined in several different ways:

1) The voting (GATF) member, usually the president or an executive vice-president. Other locations of the same company: the GATF contact, usually the plant manager.

2) The company representative to the trade organization (FTA, GTA, etc.); each location within a company is usually represented.

3) Publishers, general operations manager, etc. of newspapers as provided in the source listing.

4) Poor's Register of Corporation Directors and Executives was consulted.

Duplication was easily avoided since each list handled was checked against the existing list. GATF's membership, the largest, served as the nucleus, after certain suppliers, individuals and others known to be not applicable had been deleted.

Lists which contained no zip codes in the addresses necessitated the tedious task of determining same.

A mailing list of 1652 printers and metal decorators was compiled. Printing of the form (as well as an appropriate covering letter signed by the Executive Director of the Foundation) and other mechanical operations preparatory to posting were accomplished between August 11 and August 29. A self-addressed first class postage-paid envelope was enclosed.

In addition to those recipients who were requested to return the completed questionnaire, copies also were sent, as a matter of courtesy and information, to the executive officers of the national trade associations as well as 60 local and regional sections of the Printing Industries of America.

As requested by the Project Officer, 30 copies of the questionnaire and covering letter were forwarded to Mr. G. O. Chapman of the NAPCA Office of Program Development in Arlington, Va.

b. Follow-up Procedure to Achieve Desired Response. After six weeks, during which time the number of responses totaled approximately 200, a second letter was sent to 400 companies who had not responded to the initial inquiry. This selected list included all large companies irrespective of printing process(es) involved, all known web offset installations regardless of company size, and others, especially GATF members, having appreciable production capacity, particularly those located in urban areas. The follow-up letter was mailed October 29. A copy of the questionnaire was included for the convenience of the respondent. Response before the second mailing was 14-15% of the original distribution of 1652.

The Project Manager and Engineer were informed before their field visits as to whether or not the companies they planned to visit had returned their questionnaire. This contact afforded an opportunity for personally emphasizing the importance of cooperation and urging a prompt reply. Results were rewarding.

During the first six weeks of the survey, requests for 186 additional questionnaires were received. Ultimately, a total of 296 additional forms was requested.

In an effort to obtain additional responses, telephone calls were made in December to 18 companies, some of which are the parent company and/or corporate headquarters of plants located throughout the country. Telephone contact also induced action in a few instances.

Repeated efforts to obtain responses from a few large multi-facility companies whose data were considered vital to the survey finally resulted in receiving during April data from more than 100 plants.

2.3 Processing of Responses

Questionnaires were first identified by company and the corresponding card or cards removed from the file which constituted the list of recipients. The number assigned was stamped on pages 1 and 2 of the form and noted on the card together with the date (usually the same as or near the date received) and the number of forms included in each response. Most responses contained only one. These cards, filed according to company name, became the list of responses.

Pages 1 and 2 then were numerically coded according to state, atmospheric area (one of eight) as defined by HEW in 1968, Air Quality Region (if named, proposed or established) and plant location, i.e., commercial, industrial, etc. The first page, containing all company-identifiable data, was then separated from the other three and filed according to the response number ("plant number") assigned.

2.4 Results

2.41 Tabulation of Data

After assigning an identification number to inks, to varnishes, and to coatings, quantities were tabulated, in thousands of pounds or hundreds of gallons, according to process and to "heatset" or "other". Each tabulation also included plant number, geographical code and designation of activity ("general "printing" or "metal decorating").

A card file of solvents named in responses had been accumulated gradually and each name was assigned an identification number according to chemical composition to the extent possible. Frequently the use indicated the chemical nature of the solvent named, if otherwise not identifiable. A total of 28 numbers identified approximately 250 names of solvents (Section 2.441).

Solvent data were tabulated according to printing process(es) involved (5 "heatset" and 4 "other"), identity (as described above), use (13, including miscellaneous), and the quantity in hundreds of gallons, as well as the plant data as described above for the inks, varnishes and coatings.

Data on dryers and dryer-equipped presses were tabulated similarly according to the information requested and furnished on the questionnaire. This set of data is useful as support information and to coordinate with pollution control equipment.

Because the incidence of APC equipment (beyond modest attempts to disperse exhaust) was not high, these plants were merely listed together with a short description of the installation and the response number.

2.42 Coverage

The final response was 21.6% based on a total of 1948 questionnaires mailed out, with all considered potential responses. However, when the 47 returned as "not applicable" (possibly there were more) and the 18 returned as "undeliverable" are subtracted from the 1948 total, the response becomes 22.6%. Either figure may be considered a reasonable return. All processes are appropriately represented as are geographical areas, especially those with a high concentration of printing and metal decorating plants.

Substantially, the results are contained in Tables 3 to 13, and the merit of the survey and coverage can best be determined by examining the tabulated data. Where appropriate, statistics from other sources are included.

Since the industry perspective presented has shown graphic arts to be unique in its structure, with extremely high percentages of value concentrated in a relatively few number of companies and/or urban areas, it is extremely difficult to demonstrate here that the largest companies engaged in specific processes in each geographical area are represented in the survey without effectively disclosing data for individual companies. However, of the 22 corporations named in Fortune Magazine's May 1970 list of The 500 Largest U. S. Industrial Corporations and engaged in printing to a substantial extent, 16 are represented in the survey by at least one plant. Tables 3 through 6 in which survey totals listed with statistics from other sources on the number of establishments and geographic distribution of the market by process, indicate that the response is representative of the industry.

Geographically, the highest response areas correspond to the major market areas, but percentages are not as high, indicating that returns in other areas were disproportionately greater than the

TABLE 3

NUMBER OF COMMERCIAL PRINTING ESTABLISHMENTS
(By process)

SIC Totals	Process	Total (Class 1)[a]		GATF Survey		Response, %, by	
1967[a]		U.S.	Industry	Responses	%	Process	SIC
2752 (6830)	Lithography	6830	-	258	44.5	3.8	3.8 (Class 1) 15.8[i](Class 2)
2751[b] (12100)	Letterpress	6951[c]	-	156	26.9	0.3	2.6 (Class 1) 22.4[i](Class 2)
	Gravure	167[d]	171[e]	50	8.6	30.0	
	Flexography	443[c]	>2300[f]	94	16.2	21.2	
	Screen	393[d]	>427[g]	22	3.8	6.0	
18930				580[h]	100.0		

a. 1967 Census Preliminary Reports MC67(P)-27B-2 and MC67(P)-27B-1. Class 1, all establishments; Class 2, those with 20 or more employees.

b. Distribution of four processes not available.

c. 1963 Census, SIC 27511, 27513-27516; flexography, 27512.

d. 1963 Census, SIC 27517 - 27518 (gravure); 27519 (screen).

e. Reference 9.

f. Berger, Richard and Black, Edward. "Flexography: Growth Curve Is Up," Flexography, Vol. 14, No. 10, Oct. 1969, p. 8-9.

g. Anon. "Facts About the...Screen Printing Industry," Screen Process Magazine, Vol. 43, No. 1, Jan. 1967, p. 15-17; No. 2, Feb. 1967, p. 22-23; No. 3, March 1967, p. 30, 61.

h. Responses by process greater than plant responses (425) because of multi-process facilities; "% of GATF Survey" was calculated on 580.

i. Although number of employees was not requested in the survey, that the major portion of responses was from establishments in Class 2 (20 or more employees) is reasonably true. Therefore, coverage realistically approaches these figures.

corresponding markets. However, because of GATF's scope of contacts, the survey includes an uncalculated number of plants that are assigned by government classification to other industries (see Section 1.1) including metal decorating, part of lithography in the survey, but not reflected in the dollar volume of the process or in the government's distribution of establishments either geographically or by process. In addition, response from newspapers was sparse. Therefore, these data were included by process in commercial printing statistics (2751 and 2752), rather than designated as separate industries (SIC 3411 and 2711). Market shares of 2711 and 3411 were not included in the totals. Book printing included in the survey totals (by process only) may include some companies which are classified in SIC 2732, since neither the major product nor SIC number was requested.

Therefore, data presented (Tables 3 to 6) for the industry and from the survey are not directly comparable, but indicate that the survey results follow a pattern typical of the industry.

Without being documented in this report, it may be said that the expected response was realized, both in quality and quantity, and the cooperation of the industry was gratifying. That the newspaper industry response was low should not be interpreted as reflecting a lack of cooperation. Rather, the attitude probably was that their activity, even in offset, is at present in an area of "no concern" to atmospheric pollution, and thus their data would not be pertinent and response not important to the survey.

Only the states of Alaska, Idaho, Montana, Nevada, New Hampshire, New Mexico, North Dakota, South Dakota and Wyoming are not represented in the survey. Printing is not economically important in any of these states. Puerto Rico and the Virgin Islands also failed to respond.

2.43 Ink Consumption

The most extensive recent data available for ink consumption by process is contained in statistics furnished by an ink company for a survey conducted during 1968 (9) and a paper (26) on the consumption of chemicals in the manufacture of printing inks, authored by a member of the same corporation. Census figures do not include total poundage or assign quantities for letterpress and screen in reports on ink as a product of manufacture (SIC 2893), and members of the industry believe that Census dollar figures are understated. The

TABLE 4

ESTABLISHMENTS, SIC 2751
(By Geographic Area)

	Total (Class 1)[b]					Class 2[b,c]		
	U.S.		GATF Responses			U.S.		GATF
	No.	%	No.	Percent of: U.S.	Percent of: GATF	No.	%	%
United States	12100	100	322	2.7	100	1436	11.8	22.4
Area[a]								
New England	861	7.1	18	2.1	5.6	114	13.3	15.6
Middle Atlantic	3074	25.4	58	1.9	18.0	403	13.1	14.4
E.N. Central	2554	21.0	91	3.5	28.2	328	12.8	27.7
W.N. Central	951	7.9	27	2.9	8.4	98	10.3	22.5
S. Atlantic	1379	11.4	48	3.5	14.9	174	12.6	27.6
E.S. Central	503	4.2	15	3.0	4.7	62	12.3	24.2
W.S. Central	944	7.8	23	2.4	7.2	81	8.6	28.4
Mountain	347	2.9	3	0.9	0.9	33	9.5	9.1
Pacific	1487	12.3	39	2.6	12.1	143	9.6	27.3
Total	12100	100.0	322		100.0	1436		

a. As in Table 1 (Appendix C).
b. Class 1, all establishments; Class 2, those with 20 or more employees.
c. See Table 3 footnote (i).

most significant cause for discrepancy is that Census figures cover only shipments by commercial inkmakers and exclude a substantial quantity of captive ink made by large printers for their own use. Therefore, the quantity of inks used is assumed to be greater than the quantities manufactured and sold.

In addition, the value of ink reported as consumed in 1967 by printers classified in SIC 2751 and 2752 was only 35% of the total reported by the National Association of Printing Ink Manufacturers (NAPIM) (27). See also Table 7.

The ink market has been growing in cyclical fashion at an average rate of 5% per year since 1947 (26). For the period 1963-67 the rate was 6.5% and was expected to be no greater than 3% in 1968. However, NPAIM reported in 1969 (27) that the value of shipments realized for 1968 was $392.2 million, a 5% increase from that of 1967 ($373.4).

Although dollar values (approximate, real, and projected) are available, no statistics on quantity were found for 1968. (Even an officer of NAPIM would not estimate.) Figures for 1967 distributed according to segment of the industry, were approximate and totaled 785 million pounds, excluding textile inks.

In the preparation of Table 7, "pounds of ink" reported by the industry for 1967 was increased by 5% to calculate 1968 values, merely to reflect the market increase, not to depict accurately the total quantity or distribution by process. Figures for all except letterpress are probably low.

The 425 plants in the survey reported having used 146,845,000 pounds of ink during 1968. Using an estimated industry total of 800 million pounds, the survey accounted for 18%. However, direct comparison of all the survey results, by total and by printing process with available industry data is misleading. For instance, almost 70 million pounds of gravure ink was used by 50 gravure operations (not plants), representing about 45% of the industry-reported total, and indicating good survey coverage; but this value is inconsistent with gravure's share of the market (9% vs. 49%). Also, news ink accounts for almost 40% of the market and newspaper response was low.

A realistic approach to appraisal of the survey's being representative of ink usage in the industry is shown on Table 8. News ink was subtracted from both totals since it amounted to only 3.5% in the survey and represents 39% of the industry. Screen inks were removed from

TABLE 5

ESTABLISHMENTS, LITHOGRAPHY (SIC 2752)
(By Geographic Area)[a]

	Total (Class 1)[b]					Total (Class 2)[b]		
	U.S.		GATF Responses			U.S.		Response, %[c]
	No.	%	No.	Percent of: U.S.	Percent of: GATF	No.	%	
United States	6820	100.0	258	3.8	100.0	1646	24.1	15.8
New England (6 states)	438	6.4	22	5.0	8.5	138	31.5	16.0
Middle Atlantic (4 states)	1675	24.7	57	3.4	22.1	426	26.4	13.4
E.N. Central (5 states)	1571	23.0	74	4.7	28.7	456	35.3	16.2
W.N. Central (7 states)	563	8.2	25	4.4	9.7	156	27.7	16.0
S. Atlantic (8 states[d])	722	10.6	24	3.3	9.3	162	22.4	14.8
E.S. Central (4 states)	194	2.8	6	3.1	2.3	49	24.7	12.3
W.S. Central (3 states)	470	6.9	13	2.8	5.0	76	16.2	17.2
Mountain (4 states)	237	3.5	3	1.3	1.2	29	12.3	10.4
Pacific (4 states)	950	13.9	34	3.6	13.2	154	16.2	22.1
45 states[e]	6820	100.0	258		100.0	1646		

(footnotes on following page)

Table 5 cont'd.

a. According to 1967 Census of Manufactures Preliminary Report MC67(P)-27B-2. (Totals for 36 of 45 states also given separately.)

b. Class 1, all establishments; Class 2, those with 20 or more employees.

c. See Table 3 footnote (i).

d. District of Columbia included.

e. Five states were either not included in Census totals, not represented in GATF responses, or both.

TABLE 6

GEOGRAPHICAL DISTRIBUTION OF COMMERCIAL PRINTING MARKET SHARE vs. SURVEY RESPONSE

Area[a]	SIC 2751			SIC 2752		
	Coverage, %		Value of Shipments[b]	Coverage, %		Value of Shipments[b]
	Class 1	Class 2[c]	% of total	Class 1	Class 2[c]	% of total
New England (6 states)	2.1	13.3	6.4	5.0	16.0	6.1
Middle Atlantic (4 states)	1.9	13.1	27.9	3.4	13.4	26.8
E.N. Central (5 states)	3.5	12.8	31.9	4.7	16.2	30.0
W.N. Central (7 states)	2.9	10.3	5.0	4.4	16.0	9.7
S. Atlantic (8 states)	3.5	12.6	10.2	3.3	14.8	8.8
E.S. Central (4 states)	3.0	12.3	4.3	3.1	12.3	3.5
W.S. Central (3 states)	2.4	8.6	3.9	2.8	17.2	3.5
Mountain (4 states)	0.9	9.5	1.3	1.3	10.4	1.5
Pacific (4 states)	2.6	9.6	9.1	3.6	22.1	10.1
45 states[d]			100.0			100.0

a. As in Table 1 (Appendix C).

b. 1967 Census Preliminary Reports MC67(P)-27B-1 and MC67(P)-27B-2. Class 1, all establishments; Class 2, those with 20 or more employees.

c. See Table 3 footnote (i).

d. Five states were either not included in Census totals, not represented in GATF responses, or both.

TABLE 7

INK CONSUMPTION REPORTED - ALL PROCESSES
(By Source)

	Million Pounds							
	1967				1968			
	Census[a]	Census[b]	Census[c]	Industry[d]	Industry[e]	%	GATF	%
Lithography	26.8	80.1		80	[81.5]	11	27.37	18.6
Letterpress	91.3	-		140	[143.0]	18	28.29	19.3
News ink	-	-	328.9	310	[316.0]	39	5.20	3.5
Gravure	135.4	173.3		150	[153.0]	9	69.45	47.3
Flexography		73.4		65	[66.5]	18	16.17	11.0
Screen		-		40[f]	[41.0]	5	0.38	0.3
	253.5	326.8	581.4	785	[801.0]	100	146.85	100.0

a. MC67(P)-27B-1 and MC67(P)-27B-2 (all Commercial Printing), "Materials Consumed" table.

b. MC67(P)-28G-3 (Printing Ink). Quantities for letterpress, screen and total "not available."

c. Composited from Preliminary Census Reports of Industries not classified as printers but who included "printing ink" as a "Material Consumed." Not all industries' reports were examined.

d. From survey (ref. 9). Textile ink excluded.

e. Calculated. Ink industry figure for all printing inks of 835 million pounds (1967) (ref. 9) increased by 5% to 842 (1968). See Section 2.43.

f. Represents total of "other, including screen."

TABLE 8

INK CONSUMPTION - SELECTED PROCESSES*
(Industry vs. Survey)

	Consumption (Industry)[a]		Used (GATF)		Process Operations
	million lb	%	million lb	%	number
Lithography[b]	81.5	18.3	27.37	19.4	258
Letterpress	143.0	32.2	28.29	20.0	156
Gravure	153.0	34.5	69.45	49.2	50
Flexography	66.5	15.0	16.17	11.4	94
Total	444.0	100.0	141.28[c]	100.0	558[d]

a. From Table 7.
b. Includes metal decorating.
c. 32% of 444.
d. 397 plants.

*See Section 2.43.

TABLE 9

INKS USED DURING 1968 (SURVEY)
(By Geographic Area)

	Million Pounds					
	Lithography[b]		Letterpress	Gravure	Flexography	Screen[c]
Area[a]	G	M				
New England	0.860	0.012	0.189	0.146	0.474	--
Middle Atlantic	2.564	1.648	4.860	2.546	3.500	0.036
E.N. Central	9.706	2.071	8.616	54.137	4.465	0.212
W.N. Central	2.190	0.717	11.001	2.340	1.129	0.008
S. Atlantic	1.880	0.370	1.347	1.624	2.935	0.095
E.S. Central	1.638	--	3.758	7.660	0.605	--
W.S. Central	0.329	0.299	0.509	0.389	1.075	0.013
Mountain	0.038	--	0.958	--	--	0.004
Pacific	1.241	1.802	2.251	0.604	1.986	0.008
Total	20.446	6.919	33.489	69.446	16.169	0.376
Litho Total	27.365					

Grand Total = 146.845 million pounds

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a. See Table 1 (Appendix C) for states in each area.

b. G = general printing, M = metal decorating.

c. Factor of 7 lb/gal was used to convert those quantities reported in gallons.

the survey total and "other including screen" from the industry total. Screen printing is a small segment of both the survey and the industry and a reliable figure is not available. (In the results of the 1966 survey (24) it was stated that on the average each gallon of ink used generates $333 in sales.)

Accordingly, the survey, covering 397 plants (558 operations), a small percent by any measure, printing by letterpress, lithography, gravure and flexography reported having used 32% of the estimated industry total for these processes. Inspection of Table 8 also shows that ink usage distributed by process correlates well with market share as determined by the ink industry using both Census and industry figures.

The quantities of ink used according to process and geographic area are presented in Table 9. According to Table 1 (Appendix C), the Middle Atlantic and East North Central states locate more than 2/3 of all gravure employees. Significantly, 80% of the gravure ink used was reported from these areas. The same two areas contain approximately half of the lithographic establishments and accounted for 58% of the ink used. Other survey data compare similarly with statistics.

Approximately 80% of all the inks reported were used in lithographic, letterpress, gravure and flexographic operations in which the product was dried above room temperature.

2.431 Coatings and Varnishes

Fifty plants, mostly lithographers, reported that in addition to inks they used approximately 4.3 million gallons of varnish and 2.3 million gallons of coatings. "Varnish" may be considered as being "overprint varnish", i.e., a protective film applied after printing. "Coating" represents a pre-print film applied to condition plastic or metal substrates. In metal decorating, those surfaces which ultimately become the interior of cans also are coated.

Since the vast majority of these two materials was reported by lithographers, there is no purpose to be served by further distributing the quantities, although the capability exists. Also, there are no comparative data, except "paints, varnishes, lacquers, japans, and enamels" reported as "Materials Consumed" in the Census of Manufactures 1967 report for the metal can industry (28). This figure, approximately 22 million gallons, presumably also includes ink used in metal decorating. Varnishes and coatings used in other activity probably are categorized as "miscellaneous."

2.44 Solvents

Approximately 21 million gallons of solvents were used by the 425 plants in the survey. Distribution by process(es) is depicted in Tables 10, 10a, and by Air Quality Region in Table 11. Geographic distribution by Air Quality Region relates the industry's use of solvents to those areas of the country receiving the maximum of legislative attention. Since Regions are centered around but extend beyond large cities (two or more counties are included) and many (New York, Philadelphia, Chicago and others) are interstate, the opportunity to associate data with company source was reduced and anonymity of respondents was preserved without affecting the effort to identify those areas where solvents are used in large quantities.

2.441 Classification

For the purpose of this report, organic solvents may be classified chemically as hydrocarbons, alcohols, esters, ketones, glycols and glycol esters, and chlorinated solvents. However, in tabulating the survey data, the 250 names of solvents reported were grouped according to a schedule containing six "series," or chemical types of compounds (or mixtures), each with subdivisions, resulting in 28 numerical designations. Groups were determined almost entirely by chemical composition and/or structure. Published compilations of trade names were consulted (29-32) as well as company literature. When possible, refractive indexes were measured to assist in identification.

Hydrocarbons, which included two series (0- and 1-) and eleven numbers (01 to 05 and 10 to 15) were subdivided as follows:

Aromatic compounds (01 to 04): benzene; toluene, xylene; ethylbenzene; unsaturates and mixtures with aromatic content greater than 25% by volume.

Heatset ink oils (05) were placed in the 0- series irrespective of aliphatic/aromatic content (most are aliphatic) since all are ultimately subjected to elevated temperatures during drying in web operations.

Aliphatics and Intermediates (10 to 15) included straight-chain and branched paraffins (pentane to iso-octane), cycloparaffins (naphthenes), mineral spirits and napthas containing little or no aromatic (< 15%), heavy naphthas with higher

Table 10. SOLVENTS USED DURING 1968
(One Process Only)

Process - Ink*	Solvents (Hundred Gallons)						
	Series[a]						Total
	0	1	2	3	4	5	
1	599	3438	6111	38	-	180	10366
6	14373	20503	10580	-	723	228	46407
2	84	418	396	-	-	1	899
7	14	26	3	52	-	-	95
3	2	5	1223	-	1	-	1231
8	56	601	8957	-	-	170	9784
10	10089	24637	12868	-	12	-	47606
4	31	126	53	-	-	145	355
9	3	47	32	-	-	-	82
Total	25251	49801	40223	90	736	724	116825

*Key:

	Not Heated	Heatset or Heated
Lithography	1	6
Letterpress	2	7
Flexography	3	8
Screen	4	9
Gravure	-	10

a. See Section 2.441

Table 10a. SOLVENTS USED DURING 1968
(Two or More Processes)

Processes - Ink*	Solvents (Hundred Gallons) Series[a] 0	1	2	3	4	5	Total
1,6	145	1385	1856	-	-	55	3441
2,7	-	186	-	-	-	-	186
3,8	-	-	38	-	-	-	38
4,9	27	41	25	-	-	-	93
1,2	47	1313	317	65	-	5	1747
1,3	1	1110	469	4	-	-	1584
1,7	-	40	-	-	-	-	40
1,10	-	221	471	-	-	-	692
1,2,3	-	36	459	-	-	-	495
1,2,6	-	215	-	6	-	20	241
1,2,4	-	22	-	-	-	-	22
1,2,7	227	263	-	-	-	-	490
1,3,8	-	-	117	-	-	-	117
1,2,10	-	5	-	40	-	1	46
1,3,10	-	15	-	-	-	-	15
1,6,7	-	49	6	-	-	-	55
1,9,10	-	60	-	-	-	10	70
1,2,3,10	-	-	-	-	-	290	290
1,2,6,7	20	304	-	55	-	-	379
1,2,3,7,10	1205	28	1380	-	-	57	2670
1,2,8,9,10	14	-	-	181	-	-	195
1,2,6,7,10	-	185	-	-	-	-	185
6,7	-	201	-	-	-	-	201
6,8	-	2	-	-	-	-	2
6,2,7	-	640	-	-	-	-	640
6,7,10	5350	25435	-	-	-	-	30785
2,3	70	224	261	-	-	-	555
2,6	-	168	-	-	-	-	168
2,8	-	9	-	-	-	-	9
2,10	263	33	98	95	-	-	489
2,3,10	9	285	36	-	-	-	330
2,8,10	-	-	30	-	-	-	30
3,7,10	1107	62	2872	-	2	-	4043
8,10	8772	7671	23172	15	32	425	40087
9,10	-	-	50	-	-	-	50
7,8,10	137	3	2334	-	-	-	2474
Total	17394	40211	33991	461	34	863	92954
Table 10	25251	49801	40223	90	736	724	116825
Grand Total	42645	90012	74214	551	770	1587	209779

*Key:

	Not Heated	Heatset or Heated
Lithography	1	6
Letterpress	2	7
Flexography	3	8
Screen	4	9
Gravure	-	10

a. See Section 2.441

Table 11. SOLVENTS USED DURING 1968
(By Air Quality Region)

A.Q.R.*	Series[a] (Hundred Gallons)						Total
	0	1	2	3	4	5	
New York	3305	5012	3520	40	167	1	12045
Phila.	1085	652	16052	7	-	10	17806
Dist. Col.	75	114	317	70	-	1	577
Chicago	9841	11088	2505	-	129	51	43614
Los Angeles	1577	1506	2184	6	32	293	5598
Boston	—	223	419	-	-	—	642
St. Louis	1245	2230	867	-	51	172	4565
Pittsburgh	43	316	55	-	-	—	414
Buffalo	—	712	1	-	-	—	713
Cincinnati	92	209	488	-	-	—	789
San Fran.	1230	2932	2444	29	64	4	6703
Cleveland	5	202	10	-	-	—	217
Kan. City	466	901	1168	-	-	—	2535
Hartford, etc.	150	226	1290	-	-	—	1666
Detroit	—	188	239	-	-	138	565
Baltimore	1329	1028	1010	-	22	—	3389
Indianapolis	76	104	110	-	-	—	290
Minn.-St. Paul	968	1399	2066	-	42	—	4475
Milwaukee	2614	8117	5193	9	27	—	15960
Prov. (R.I.)	6	28	945	-	-	—	979
Seattle	390	705	460	-	14	—	1569
Louisville	3331	5013	543	-	-	—	8887
Dayton	2	97	80	30	-	105	314
Houston	236	732	439	-	32	—	1439
Dallas	1477	150	941	-	-	—	2568
Toledo	16	65	81	-	-	—	162
Atlanta	617	854	665	-	40	—	2176
Memphis	1600	—	401	-	-	—	2001
New Orleans	442	606	266	-	13	—	1327
Miami	—	19	147	-	-	—	166
Omaha	—	1822	56	-	-	—	1878
Beaumont	77	94	989	-	-	—	1160
Port. (Me.)	286	265	108	-	9	—	668
	32559	67631	46059	191	642	775	147857
Others (10) (<10,000 gal.)	48	388	87	-	-	6	529
None	10038	21993	28068	360	128	806	61393
TOTAL	42645	90012	74214	551	770	1587	209779

* Metropolitan area which is center of Air Quality Region, established, proposed or named by HEW through 1969.

a. See Section 2.441

aromatic content (15-25%), turpentine, Stoddard solvent and the like. In some instances, numbers were assigned arbitrarily because only partial identification was made. However, data available were sufficient to indicate that classification in this series was proper. One number was reserved for "hydrocarbon, composition unknown" and one for "hydrocarbon + various other components including esters."

Oxygen-containing compounds (2- series, 20 to 29) included methanol, ethanol, propanol and isopropanol, butanol and isobutanol, glycols and glycol esters, acetone and methyl ethyl ketone, branched and cyclic ketones, esters, and mixtures of oxygenated compounds.

Chlorinated compounds (3- series, 30 to 34) included trichloroethylene, trichloroethane, methylene chloride and two commercial solvents presumed to be principally, if not entirely, chlorinated paraffin.

Nitrogen-containing compounds (4- series, all designated as 40) included nitroparaffins and dimethyl formamide.

Miscellaneous (5- series, all as 50) included small amounts of various solvents, quantities not specified (given only as totals) and trade names not identified but suspected of being commercial detergents. With persistence, most detergents were identified and deleted.

2.442 Use

The purpose for which each solvent was used also was numerically designated to make this information compatible with other data. Twelve numbers were used to indicate ink diluent, washes, fountain solution additive, thinner for varnish or coating, platemaking and miscellaneous. An additional number designated an inclusive nonspecific use as ink diluent and wash-up and was assigned where other information indicated that the portion (unknown) used as ink diluent ultimately was heated.

Quantities specified for use as ink diluent (44%) and the various washing activities (14%) accounted for 58% of the total. An additional 11%, reported used for both purposes was not distributed. The ratio overall of ink diluent to washes as reported was 7.6 to 1. Distributing the 11% accordingly increases the percentage used as ink diluent to 52% and as washes to 17%.

Varnish and coating thinner represented 13%, and all other uses 18% of the total. Additional data are presented in Table 12.

Table 12. SOLVENTS USED DURING 1968
(By Use)

Use*	Solvents** (Thousand Gallons)				% of Total
	01-05	10-15	20-29	Total	
10	1841	3992	3452	9285	44
20-26	579	1774	519	2872	14
40	614	1156	984	2754	13
70	611	317	1365	2293	11
Total	3645	7239	6320	17204	82
Other (all series)				3774	18
				20978	100

* 10: Added to ink before using.
20-26: Washes (press, roller, blanket, etc.).
40: Coating and varnish thinner.
70: Wash-up + diluent for ink destined to be heated; combination of 10 and 20-26. Distribution not given. (See also Section 2.442.)

** 0-Series: aromatics, unsaturates, heatset ink oils
1-Series: essentially aliphatic
2-Series: oxygenated compounds (alcohols, esters, ketones, etc.) (See also Section 2.441.)

Approximately 83% of the ink used in lithography, letterpress, gravure and flexographic processes involved drying above room temperature. Since less than 7% of the plants reported that volatilized emissions were incinerated and the incidence of solvent recovery equipment was less, much of the 12 to 14 million gallons of solvent used as ink diluent and varnish thinner ultimately was vented to the atmosphere during drying operations.

2.5 Emission Control Equipment

As expected, not many plants reported having control equipment and those who do are in those areas of the country where strict legislation exists regarding organic emissions. As will be seen in Table 13, some plants have attempted to physically disperse the effluent. Since response from the gravure industry was high and only two plants reported having solvent recovery units, apparently the economics of solvent recovery per se have not been demonstrated. Some filters exist in binding operations and for metallic vapors in letterpress.

TABLE 13

APC INSTALLATIONS
(From Survey)

Equipment	Plants	Process
Incinerators*	28	Lithography, Gravure
Solvent Recovery	2	Gravure
Filters (particulates)	6	Lithography**, Gravure, Letterpress
High Stacks (dispersion)	11	Lithography

*Thermal and catalytic
**Binding operation

3.0 FIELD VISITS

3.01 Introduction

Area field trips were planned to various geographical areas of the country to supplement the formal mailed survey, accrue data on sampling and analysis methods for measuring emissions, and evaluate air pollution control technology applicable to the graphic arts industry. Having established an initial perspective for the study, a plan was formulated for specific field visits. Companies with appreciable air pollution control experience were identified and listed by geographical location for use in establishing the personal visit schedule. In all, it was estimated that 50 or more plants might be visited. The total field count shown in Table 14 (Appendix C) far exceeded this requirement.

3.1 Establishing Geographical Priority

Recognizing the fact that several areas of the country had experienced air pollution control activities much sooner than other areas, a priority for the personal visits was established on this basis. Companies with experience in air pollution and its control provided valuable information. Consultants, as well as local air pollution control agencies operating in some areas of the country had performed source testing and had developed sampling and analytical techniques in order to determine compliance with local air pollution requirements. Suppliers to the industry, particularly air pollution control equipment manufacturers, had installed control devices and thus some engineering, cost and operational data were available. This type of material added substantially to the study.

Initially, Pennsylvania based companies and suppliers to the industry were visited thereby providing valuable industry exposure to staff members. In certain respects the information obtained was characteristic of the type of information that would be available from industry operations. The scheduling of company contacts and the manner in which the data were gathered in these initial visits served as the approach that was used throughout the duration of the visits. So that the field trips would be as productive as possible, all contacts in a given geographical area were sent a letter stating the purpose of the visit and requesting that certain types of information be assembled prior to the actual field contact. This helped field personnel to conduct interviews more efficiently. The type of data requested from industry participants is outlined in Section 1.21 of this report.

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By arranging the field trips into geographical areas it was possible to visit companies, suppliers, consultants, etc., all located in that area thus obtaining maximum area exposure in a minimum of time. Generally, the length of the field trips was of a one-week duration; however, the number of contacts in certain areas of the country was so numerous that an additional week was required in those instances. The various sections of the country visited and the number and type of industry contacts made is outlined in Table 14 (Appendix C).

3.2 Discussion of Field Visit Tables

Tables 15 through 19 (Appendix C) list the plant data obtained in five major geographical areas of the country. One primary goal of the Phase I effort was to gain a representative perspective of the technical aspects of emission control by defining materials, processes, emissions and control technologies within the graphic arts industry. To this end, the field visit tables organized by geographical area summarize the data accumulated in the various printing processes.

Process studies were made at 29 plant locations employing lithography, 10 in the letterpress process, 8 using gravure, 3 employing flexography and finally 10 metal decorating plants. The plant visitations studied have been coded sequentially so that 1-G indicates the first gravure installation studied, 1-F the first flexographic, etc. (The coding was utilized to maintain individual company anonymity.)

Characterization of the plant operations is provided by data tabulated in Tables 15-19 (Appendix C). Abbreviations were used extensively and can be located in the Key to Tables 15-19 (Appendix C). In all cases the code, process and equipment utilized are shown under the column entitled "Process/Equipment." Next, "Materials Consumed;" namely, paper and ink (in the case of metal decorating, metal sheets) are listed. Where figures are only estimates, they are so indicated and where information was not available, it is indicated by the abbreviation "n.a." Information on the drying equipment, specifically the type, number of units, air flow and temperatures are listed under "Drying Equipment."

In the event that the facility visited could be used in further task work, i.e., field sampling, information was gathered on the stack geometry, as to whether it was a single or manifolded stack system and as to its suitability for sampling. Also indicated in the tables is the type of control equipment, if any.

These tables have been established solely on the basis of information gathered from the field visits and as a guide for future task work. No claim is made that these processes are representative of the entire industry; however, in the case of certain processes and on the basis of the number visited, some process generalizations may be possible.

3.3 Field Observations

The amount of data furnished the investigators was limited in the case of plant visits to the knowledge of the operation by plant operating personnel. Several areas of information requested of companies during the field visits were unproductive for various reasons. These areas generally included operating data on the dryer and air pollution control equipment where available, material consumption rates (in the case of amount of ink and paper used), percent of time in operation, and total production estimates.

It is probably typical of most small plants that air flow in exhaust equipment (dryers) is not measured. Control of the press equipment is accomplished by observing the quality of the product, in this case the dried sheet. Further adjustments in air flow are made until little or no smoke is seen leaving the dryer at the openings for the web entrance and exit. Thus, there is no plant operational need to measure flow rates. Additionally, temperature of the web as recorded by most plants also serves as a control and further negates the requirement for measuring flow rates.

In most plants little is known on actual fuel consumption (natural gas, etc.) since fuel used for drying and air pollution control consumption are not isolated according to applications in the plants. It appears from field observations that web printers and metal decorators have an excess capacity built into their drying systems evidently to make sure that all jobs can be properly dried. Several of the air pollution control equipment manufacturers also mentioned that some drying systems are operated at flow rates in excess of that required for proper drying, and although this may assure good quality control of the product, it is more costly in terms of fuel requirements to handle the larger volumes of air.

The cost of operation of control equipment is directly related to the volume of air discharged by the process. Therefore excess volumes of air require additional costs of operation.

Press rates and percent of time in operation were difficult to obtain because these numbers are so variable depending on the scheduling of jobs, their quality and duration, makeready difficulties, and other process conditions.

One approach to the question of production rates was an attempt to determine the total square feet of printed matter produced in any year or monthly period. It became apparent to the investigators that most printers regard information on total production versus number of printing units to be a sensitive barometer of the economic position of a plant relative to the industry. Information on the financial condition of printers is regarded as proprietary under any conditions.

Suppliers to the industry, particularly ink manufacturers, were also hesitant to provide any information which could reveal their economic health. Total production, sales to geographic areas and ink formulations were virtually unobtainable. In the area of ink formulations, only that information available in published literature was provided.

New developments in dryers, control equipment and inks (if any) could not be obtained mainly because this area is highly competitive. Medium or high velocity hot air drying of webs seems to be the most popular method. Combining the dryer or oven with pollution control equipment and adding heat exchangers appeared to be the route printers have taken when faced with control requirements under existing pollution laws or codes. Control techniques for the most part have taken the form of more established methods, that being thermal or catalytic incineration and adsorption using activated carbon. Discussions with control equipment manufacturers indicated little or no activity in the area of new or novel approaches to control as applied to the graphic arts industry.

Finally, in attempting to obtain available industry emission data, the investigators found emission data relatively scarce. This is primarily due to the fact that only certain sections of the country have come under pollution regulations and also that there are no universal, commonly accepted testing techniques when evaluating emissions from the graphic arts industry.

Other less important reasons for lack of available emission data are:

1. Some of the emissions data cannot be released, especially where local control agencies use emissions data for enforcement.
2. There can be disagreement between data obtained by two or more laboratories at the same time under the same conditions.
3. Operating conditions are not stated completely for some results.
4. Operating conditions vary widely from one set of data to another.
5. Comparisons of one set of data to another are difficult as operating conditions vary widely.
6. There is considerable confusion over proper sampling methods, analytical methods and interpretation of results.
7. Many local agencies have put available money into continuous ambient air monitoring, using infrared and ultraviolet absorption and have not concentrated on stack sampling for organics.
8. Other local agencies are still enforcing older legislation based on visible smoke emission and nuisance clauses.
9. Some printers on the west coast have avoided the necessity of installing fume burning equipment by reformulating their inks and/or coatings.

4.0 SAMPLING

4.1 Introduction

Work required by the contract in this area can best be divided in the following manner: (a) conduct literature search to determine applicability of emission-measurement equipment in use throughout the graphic arts industry; (b) contact air pollution control equipment suppliers and survey (by personal contact as part of the field trips) persons associated with air pollution control efforts for information to aid in determining a suitable, reliable and simple as possible method for measuring emissions for (future effort); (c) design and assemble measuring equipment based on the work in the above two areas; and (d) recommend a plan for sampling source sites, using an accepted technique of emission measurement developed as part of an overall source sampling program.

In order to understand methods of sampling, emission measurement and a source sampling program as it may apply to the graphic arts industry, the types of pollutants must be classified. Basically, pollutants are either gaseous or particulate; however, in the graphic arts industry these areas are too broad. By subdividing the major classes of pollutants, the important gaseous ones can then be specified and classified. Table 20 (Appendix C) outlines this classification. Comments as to the suspected occurrence of the pollutant within graphic arts processes are provided.

4.2 Methods of Sampling

4.21 General Aspects of Source Sampling for Gaseous Pollutants

Source samples are taken to determine the nature and quantity of the pollutants emitted by the process. The samples may be used to determine the air pollution potential of the process, to verify compliance with control regulations or to investigate the efficiency of the process equipment or pollutant abatement equipment.

When planning a sampling program for gaseous pollutants, the methods of analysis that can be performed on the collected sample should be understood. In order to coordinate analytical and sampling procedures, the methodology and limitations of each type of analysis in addition to the interferences and limitations of the sampling procedure must be evaluated (34).

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4.22 Grab Sampling Principle

A "grab sample" is a sample taken at a particular time within a defined time interval. Its primary importance lies in the fact that it provides for the determination of gaseous concentration since the sample is extracted over a short period of time. Grab sampling is useful when it is desirable to obtain (34):

A. Variation of gas concentration with time.
B. Variation of gas concentration across a section of ductwork.
C. The maximum (peak) or minimum concentration.

It should be noted, however, that the sensitivity of grab sampling to components whose concentration approximates the sensitivity of available analytical methods can at best be described as questionable. Most grab sampling techniques utilize a minimum of equipment and require little or no special training or experience on the part of the operator (35).

A common collection technique used in grab sampling is the use of evacuated containers (glass or metal). An evacuated flask sampling train can be designed to meet specific situations. Heating tapes can be used on the sampling probe inserted into the duct to maintain the temperature of the sampling train above the dew point of the gas stream being sampled. Leakage can be avoided by using precision needle valves instead of poorly fitted stopcocks. As an additional safeguard, leakage can be checked by recording the pressure readings at the sampling site both before and after the sample is collected. A schematic description of a gaseous sampling train using an evacuated cylinder is shown in Figure 2 (Appendix B).

4.23 Continuous Sampling Principle

A "continuous sample" is a sample taken from the effluent stream over a relatively long period of time. The objective of taking the sample is to obtain the average gaseous composition during the time interval over which the sample was taken (34).

Continuous samples are collected by the use of a sampling train at a regulated flow rate. Grab sampling techniques can be modified to take a continuous sample by the utilization of a device to indicate and regulate the sampling flow rate.

Continuous sampling is desirable when large sample volumes are required or when an average concentration over a period of time is desired. It is especially applicable when stack conditions are uniform or vary relatively slowly. If the stack flow fluctuates rapidly and widely without any consistency, grab sampling should be considered or the continuous sampling time should be of such duration to allow the fluctuations to average out (34).

Most gaseous sampling trains used in continuous sampling consist of a filter, probe, gaseous collector, meter, flow regulator and gas mover (i.e., pump). A variation in gaseous sampling trains and one which has been utilized in the graphic arts industry is shown in Figure 2 (Appendix B). Although this sampling train essentially is based on the grab sampling principle, the evacuated cylinder serves as the gas mover and thus could be considered a continuous sampling device.

4.24 Sampling Methods Utilized Throughout the Graphic Arts Industry

Both sampling principles - grab and continuous - as well as modifications thereof have been followed in methods used in graphic arts processes. Summarized in Table 21 (Appendix C) are the various sampling techniques (with basic hardware) known to be in use throughout the industry. No claim is made that the table includes all methods currently in use, but the major techniques are presented. Some variation exists but much similarity is apparent.

Most of the methods are based on the premise that the pollutant concentration in the stream is steady and uniform and that by grab sampling the average concentration in the stack can be obtained. Also, small volume gas collectors were developed according to the subsequent analytical method.

Personnel of the Physical Measurements Laboratory of Mellon Institute of Carnegie-Mellon University (sub-contractor in the study) evaluated the various sampling procedures and recommended a suitable apparatus incorporating the above ideas. Designed primarily for grab sampling the apparatus was modified to allow continuous sampling by including a flow regulating device. Thus the apparatus possesses maximum sampling capability.

4.25 Sampling Method to be Used by GATF

Upon review of established and field-tested techniques in sampling a prototype field sampling apparatus was assembled by personnel of Mellon Institute and field-tested by GATF.

The apparatus consists of a 300-ml stainless steel cylinder with a threaded opening at both ends. A vacuum gage is attached to one end (the lower opening when held in a vertical position). The upper opening connects to a union, a needle valve, a second union and a fabricated double-tee fitting which connects to the U-shaped trap. After the trap, another union is used to attach the sample probe. When the trap is detached, each end is plugged before removing from the dry ice bath. Both trap and probe are 1/8" stainless steel tubing. The sample probe length was set at two feet. (This length can be changed depending on width of stack and sampling location.) The trap is 14" long,approximately 12 inches of which is immersed in the dry ice.

The volume of gas sample needed for analysis will depend primarily on the sensitivity of the analytical method and the concentrations of given components in the gas stream. It is this consideration which forms the basis for selection of particular sampling equipment and analytical methods to be employed.

Two factors were considered in selecting the dimensions of the gas sampler:

1. Since the trap contains normal air which is swept into the cylinder during sampling, a correction factor (see below) must be applied to determine the actual sample volume.

2. All of the condensible material must be injected at one time into the chromatograph during analysis; consequently, the size of the cylinder should be compatible with the anticipated upper and lower concentration limits of the condensibles.

A 300-ml sample cylinder and 1/8" O.D. 24 gage tubing will yield only a 1.7% correction to the cylinder contents. Assuming a maximum concentration of condensibles (on the order of 1,000 ppm), the trap would contain a 0.2 mg sample for injection into the chromatograph. The procedure is to attach the trap, position it in a steel Dewar flask and surround with crushed dry ice. The probe is then aligned and inserted into a hole in the duct. Space around the probe can then be sealed. Some practice is necessary in order to collect the sample at an even, slow flow rate approximating 20-ml per minute. Using a 15-minute sampling period requires constant adjustment of the needle valve to achieve this rate.

Several improvements in procedure are possible with the sampling equipment. The trap length can be increased one or two feet if the tubing is coiled. An additional refinement is to add firebrick-type column packing to the trap, or to use a glass wool plug. Either material will help to trap condensible materials because of the increased surface area and prevent them from being swept out of the trap. Finally, provisions can be made easily to plug both ends of the sampling probe after taking a sample if it is found that condensible material is collecting in the probe. Phase II of the program will provide a means to evaluate these improvements.

4.3 Source Sampling Requirements

4.31 Determination of Gas Flow Rate

Practically all source tests include the measurement of the flow rate of gases at one or more locations in the equipment or process being tested. The preferred method is direct measurement of average gas velocity by pitot tube procedures. The product of the average velocity and the cross-sectional area of the stack at the location of measurement then gives the flow rate (35).

A. Sampling Location

Test locations may be at the top or outlet of the stack, or at some other point in the stack. They may also be located in the ductwork leading to or within the control equipment, dryer or oven ducting, chill roller exhaust or a stack directly from a press operation. Generally, holes must be made to allow access to the gas stream.

Gas velocity measurements should be made at the same point where samples are to be taken. The sampling sites should be situated at points where the gases have been well mixed and are free as possible from distortion or non-uniformity of flow. Disturbances can be created by a dilation or a constriction in the stack, by changes in the direction of flow caused by bends or obstructions, or by inlet or exit gas streams in branch ducts.

Normally, the sampling location should be at least eight diameters downstream from any bend, expansion, contraction, or visible flame in the stack or flue, and at least two diameters upstream from any bend and obstruction.

Should the above prove impractical use the following "rule-of-thumb": (34)

1. For a straight flue run of six to eight stack diameters in length, approximately double the number of sampling points.
2. For a length of four to six stack diameters, approximately triple the number of points.

However, many cases will be found, usually at inlets to control equipment, or from some outlet stacks, when measurements must be made at points closer to the disturbance. Flow measurement and sampling techniques must be carefully applied to minimize errors that may result from compromises necessary in the selection of a sampling location.

B. Measurement of Gas Velocity

The theory of measurement of velocity of flowing liquids and gases by use of pitot tubes is covered extensively in standard engineering references such as that by Perry (36). A commercial pitot tube called the standard type is made of stainless steel for use at elevated temperatures. As shown in Figure 3 (Appendix B), it consists of two concentric tubes bent at a right angle, with the inner tube open at the tip (37).

The opening of the inner tube, when directed against the gas flow measures the total (impact) pressure of the flowing gas (35). The outer tube measures the static pressure of the gas through a number of small holes drilled through the tube wall between the tip and the bend, perpendicular to the impact opening. The difference in pressure between the two tubes is equal to the velocity pressure, or "velocity head" of the gas at the point of measurement. The pressure difference is then measured with an inclined manometer connected to the taps of the pitot tube.

The basic formula expressing the velocity of a moving gas, as measured by this method, is:

(a) $$V_s = \sqrt{2gh}$$

where

V_s = velocity of the gas in feet per second.
g = acceleration due to gravity in feet per second per second.
h = height of column of the gas, equivalent in pressure to the velocity head reading.

With the pressure of the gas equal to 29.92 inches of mercury, and the density equal to that of air, the above formula can be written as:

(b) $$V_s = 2.90\sqrt{HT_s}$$

where

H = gage reading in equivalent inches of water.
T_s = absolute temperature of the gas (absolute temperature = degrees Fahrenheit + 460).

If the pressure of the gas differs from 29.92 inches of mercury or if density is different from that of air then formula (b) must be modified to read:

(c) $$V_s = 2.90\sqrt{\frac{29.92}{P_s}\left(\frac{1.00}{G_d}\right) HT_s}$$

where

P_s = absolute pressure of the gas in inches of mercury in the flue being tested ($P_s = P_{atm} + P_g$)
$P_g = -\Delta H/13.6$
G_d = specific gravity of gas referred to air (28.95) molecular weight.

In cases where the gas stream is suspected of being moisture laden such that moisture can clog the small static pressure holes in a standard pitot tube, a type S (Stauscheibe) pitot is used (35).

This type of tube is shown in Figure 4 (Appendix B). This pitot tube produces a reading somewhat higher than the true velocity head or pressure, so a calibration correction (normally between 0.8 and 0.9) must be applied when calculating gas velocity. The formula given in equation (b) can then be expressed as:

(d) $$V_s = 2.90\ F_s\ \sqrt{HT_s}$$

where F_s the correction factor must be determined from a comparison with a standard pitot tube (37). (F_s averages 0.83 for velocities up to 50 feet per second.)

The pitot tube and inclined manometer constitute a null-balance system in which there is no flow of gas through these components. This is an advantage of the use of the pitot tube compared with other flow measurement devices when hot gases are present.

4.4 Measurements and Calculations

4.41 Velocity Traverse

Since the pitot tube measures velocity head only at the point in the gas stream where it is placed, readings must be made at a number of points in the stack cross-section so that the average gas velocity may be calculated (35). The number of points to be used and their location can be readily determined in accordance with commonly accepted practice.

The cross-sectional area of the stack at the sampling location is divided into a number of concentric equal area zones for circular stacks, Figure 5 (Appendix B), or rectangular equal areas for rectangular stacks Figure 6 (Appendix B) (35). The number of areas used depends on the flow pattern and the size of the stack. For circular stacks, with fairly uniform flow, the usual practice is to employ the number of areas shown in Table 22 (Appendix C) (34). In rectangular ducts or stacks, holes are located to conveniently traverse the centers of the areas with the pitot tube. The minimum number of equal areas in the rectangular ducts or stacks is shown in Table 23 (Appendix C).

The traverse points for velocity head measurements are located in each area as suggested in Figures 5 and 6 (Appendix B). With rectangular ducts or stacks, these points are at the center of each rectangular area, Figure 6 (Appendix B). For circular stacks, Table 24 (Appendix C) may be used where point locations are indicated as percent of circular stack diameter from inside wall to traverse point (34).

When test holes are necessary in circular stacks, two holes are made, along diameters at right angles to each other, large enough for the insertion of the pitot tube, sampling probe and thermocouple. With rectangular ducts or stacks, holes are located in such positions as to conveniently traverse the centers of the rectangular areas with the pitot tube.

In making the actual velocity traverse, the pitot tube is moved along the stack diameter, reading the velocity head at each traverse point with an inclined manometer. Gas temperature is recorded and monitored throughout the traverse. Static pressure in the stack is recorded for subsequent use in the flow equation (c). Normally, three complete traverses are made in order to calculate a reliable average stack gas velocity.

Before and during the traverse, certain points should be kept in mind:

1. The longer the length of the pitot tube, the greater the accuracy of the traverse (normally 36" is considered adequate for graphic arts processes).

2. Use of a long length of tubing from the pitot tube to the inclined manometer will minimize fluctuation in the manometer and error in reading.

3. The manometer, tubing, and connections should be tested for leaks.

4. The sampling port should be sealed as tightly as possible when taking velocity head readings to minimize any effect on the static pressure of the stack gases adjacent to the opening. This is especially important when using a Type "S" tube.

4.42 Calculations of Gas Volume

The gas flow rate at stack conditions can be expressed as:

$$(e) \qquad V_o = 60\ (\overline{V_s})\ (A)$$

where

V_o = volume of gas in cfm at stack conditions
$\overline{V}_s$ = corrected average gas velocity, feet per second
A = cross-sectional area, square feet

For use in air pollution work this volume of stack gas is normally expressed as corrected to standard conditions (60°F and 29.92 inches of mercury).

$$(f) \qquad V_{std} = V_o \left(\frac{Ps}{29.92}\right) \left(\frac{520}{T_s}\right)$$

where

V_{std} = volume under standard conditions
V_o = volume of gas at stack conditions
P_s = absolute pressure of gas in the flue being tested
T_s = absolute temperature of the gas (^oK)

4.43 Measurement of Gas Temperature

Measurement of gas temperature is generally accomplished by use of a pyrometer. For purposes of this report a pyrometer is an instrument for measuring temperature using a thermocouple and extension wire. This measurement can be supplemented by use of a stack-type glass tube thermometer or stem-type thermometers. Pyrometric instruments have the advantage of being used in various temperature ranges, provide instant read out, have no need for standard cold-junction reference, and provide temperature measurement within a 1% accuracy limitation.

4.44 Measurement of Gas Pressure

The static pressure of the stack gases usually differs little from atmospheric. The difference can be measured either with the static pressure tap side of the pitot tube, or with a regular pressure tap, connected to one leg of a manometer. The static pressure is simply the algebraic sum of this pressure difference and atmospheric pressure. Atmospheric pressure can be measured by several instruments, however, field type portability is a prime requisite. An instrument with this capability is the temperature-compensated aneroid barometer. Other measurement means, although providing greater precision than the aneroid barometer, are not readily portable, examples being the mercury manometer type barometer and the absolute pressure manometer.

4.45 Measurement of Water Vapor

In an effluent stream such as that from printing or metal decorating, a non-saturated condition occurs. It is anticipated that the proportion by volume of water vapor in the duct gas will be less than 15% or a dew point less than 126°F. A motorized psychrometer utilizing a wet-and-dry bulb temperature method can be used to determine water vapor pressure. If it becomes impractical to determine wet-and-dry bulb temperatures within the duct, the duct gas could then be drawn through flexible tubing by a pump for determination by a psychrometer at a point removed from the duct. The moisture content may then be calculated from the following equations (34).

$$\text{(a)}\quad e_A = e'' - 0.000367\ P_a\ (t_d - t_w)\left(1 + \frac{t_w - 32}{1571}\right)$$

where

e_A = water vapor pressure in the gas mixture as obtained
e'' = saturated water vapor pressure at t_w
P_a = atmospheric pressure
t_d = dry-bulb temperature
t_w = wet-bulb temperature

$$\text{(b)}\quad B_w = \frac{e_A}{P_a}$$

where

B_w = moisture content
e_A = water vapor pressure

4.46 Measurement of Specific Gravity of Duct Gas

Calculation of gas velocity requires that the exact specific gravity of the gases be known. For field calculations where an approximate value is sufficient, such as sampling rate determinations, the value of G_d (ratio of flue gas specific gravity to that of air [28.95] may be considered to be unity. For most flue and stack gases, the value $\sqrt{\frac{1.00}{G_d}}$ "gas density correction factor" will

will be slightly greater than unity due to the presence of water vapor, but will seldom exceed 1.05. For steam, this factor is only 1.27.

4.5 Industry Source Sampling Plan

4.51 Introduction

Regardless of the ultimate use of the information obtained from a source test, the prime objective always is to obtain reliable data on the composition of the effluent and its rate of emission to the ambient atmosphere (35).

Source testing, from initial planning to a final report, is a multifaceted activity. Although the factors to be considered will be common to all operations (except existence of APC equipment), the size and complexity of a given operation will determine the effort involved and ease of accomplishment. Proficiency acquired with repeat performance will influence time to accomplish.

4.52 General Procedures

The following list includes general procedural steps and descriptive data for each test which comprise a source sampling plan.

(a) Background information on the source
(b) Inspection of source for physical test requirements
(c) Selection of test procedure
(d) Scheduling the test
(e) Measurement of exhaust gas(es) and flow rate(s)
(f) Recording of plant operating data
(g) Characterizing physical appearance and odor of effluent
(h) Collection of effluent samples in duplicate from process
(i) Collection of effluent samples for efficiency calculation of APC equipment (if any)
(j) Obtain specimens of ink, coating and substrate(s) used
(k) Processing and analysis of effluent samples
(l) Calculations from field and laboratory data
(m) Preparation of test report

4.53 Planning a Source Test

1. Intelligent planning of a source test requires an understanding of the purposes and ultimate uses of the data sought, and adequate information on the process to be tested or evaluated.

2. When the emission source or control equipment has not been tested previously, a preliminary visit to the test site by source test personnel is recommended. The optimum locations for gas flow measurements and sampling should be selected. In all cases it will be necessary to allow time to prepare test holes, hooding (if required), test platforms, or scaffolding. These are normally furnished by the plant management; however, if required the testing personnel should be equipped with tools and portable scaffolding for gaining access to many sampling locations.

   Also to be considered during the plant inspection is accessibility, space requirements, availability of electricity, the operating schedule of the plant equipment, estimates or preliminary measurement of temperatures, pressures, velocities, and moisture content of the gas streams. It is evident that the amount of information and planning needed will vary greatly, depending upon test requirements and familiarity of testing personnel with the test site.

3. To summarize the planning for a source test, the following points should be considered (35).

   (a) Samples of the emissions collected for analysis must be representative of the gas stream being sampled.
   (b) Volume of gas sample withdrawn for analysis must be measured in order to calculate the concentration of material in the gas stream.
   (c) The gas flow rate from the source must be determined in order to calculate emission rates for the various constituents.
   (d) The test must be conducted under conditions representative of the operating characteristics of the equipment where applicable.
   (e) Accurate results will depend upon selecting the correct flow rate measurement sampling and analytical techniques.

4. When scheduling the actual test, the date selected must allow sufficient time following the original plant inspection for preparation of test facilities, and for providing personnel and equipment needed for the tests. The date also must be coordinated with plant management personnel to insure that the facilities will be operating under conditions as specified for the testing program.

4.54 Collection and Analysis

Techniques have been developed for the collection and analysis of several specific gaseous contaminants. Many of these contaminants may have little or no applicability to the graphic arts industry. Among these are:

1. Ammonia and ammonium compounds
2. Oxides of nitrogen
3. Oxides of sulfur
4. Oxidants
5. Chlorine and chlorine compounds

Of importance in the sampling plan for the printing and metal decorating operation will be hydrocarbons and the oxides of carbon. (The analysis technique for these gaseous contaminants can be found in Section 5.0 of this report.) Of secondary importance are organic acids, formaldehyde, and other aldehydes for which developed techniques of collection and analysis can be found in the literature. Based on field studies and available emissions data, the amount of particulate matter in the effluent stream is expected to be negligible and thus sampling will be confined to only gaseous contaminants as outlined in the analytical section of this report.

4.55 Efficiency of Air Pollution Control Equipment

In those printing and metal decorating processes operating with emission controls, sampling and analysis to determine efficiency will be used. By sampling both the gas entering and leaving the apparatus simultaneously, and dividing the outlet concentration by the inlet concentration, the percent loss is calculated. This value subtracted from 100 equals the percent efficiency.

A formula that may be used to calculate incinerator efficiency is:

$$100 - \frac{\text{outlet Cppm} \times 100}{\text{inlet Cppm}} = \%\ \text{efficiency}$$

4.56 Visible Emission Evaluation

Since many municipal, state and federal regulations prescribe smoke-density limits based on the Ringelmann Smoke Chart, as published by the U. S. Bureau of Mines, visible emission evaluation must be a part of any basic source sampling plan. In order that this data have future validity, readings should be recorded on a data sheet preferably of the type used by most regulatory agencies.

The following procedure will be used in recording visible emission:

1. Gray and black smoke will be read in densities and recorded in Ringlemann numbers.
2. Any other colored emissions are recorded in opacities and recorded as percentages. (Based on the equivalent opacity standard.)
3. If possible, the sun will be at the observer's back during daylight hours.
4. The light source will be behind the plume during hours of darkness.
5. If possible, readings will be taken at right angles to the wind direction and from any distance necessary to obtain a clear view of the stack and background.
6. Readings will be made through the densest part of the plume and where the plume is no wider than the diameter of the stack.
7. Observations will be recorded immediately, looking away from the plume between readings thus avoiding eye fatique and erroneous readings.
8. All information will be recorded in appropriate spaces on the data sheet with readings being taken at 15-second intervals.
9. Any changes in the color of the plume will be noted in the remarks column.
10. Any hour of readings will mean any consecutive sixty-minute period.

4.57 Odor Measurement

Any method of odor detection and comparison must rely to some extent upon the sense of smell. In view of the fact that the response of the human olfactory system does not allow an absolute or quantitative measurement of odor intensity, only relative intensities of odors can be compared. Relative levels can be determined by comparing the dilutions to which each of two or more odorous gases must be subjected in order that equal odor intensities result. As individuals vary widely in their relative sensitivity to odors, test panels are used, and the comparisons of relative odor intensities are made by diluting each odor to its limit of detectability, called the odor threshold.

Field testing personnel can attempt evaluation of odors by use of (a) a Scentometer and (b) a determination of the odor intensity and quality at the point of discharge of the gases into the atmosphere. The Scentometer (38) can be used to determine an order of magnitude of the concentration of an odorant in air. This instrument is essentially a rectangular plastic box containing two chambers of activated charcoal, two nasal ports for sniffing, two 1/2" diameter air inlets (one for each activated charcoal bed), and four odorous-air inlets (1/16", 1/8", 1/4" and 1/2" diameter). The odorous inlets are connected directly to a mixing chamber and the nasal outlets. The unit of expression most suitable for this work is the number of times that the odor is as strong as its threshold concentration or the number of dilutions with pure air needed to dilute it to the threshold concentration. This expression can be written as D/T (dilution to threshold). The four sizes of odorous-air inlets were selected on the basis of laboratory tests of the most practical set of inlets for field use.

In addition to use of the Scentometer, odor intensity and odor quality (two perceptual attributes of odor) may be evaluated by field testing (39). The Olfactory Method (39) makes use of the human nose. Intensity can be measured by reference (relation of physical to mental) to some psychophysical scale. For example:

O - No odor
1 - Just detectable
2 - Definite
3 - Strong
4 - Overpowering

Intensity measurements may be improved by comparison to a reproducible series of standard odorant intensities since the nose can differentiate about 30 different intensities (39).

The odor quality identifies odor through resemblance to some known odor. Here a Crocker & Henderson Scale (Four Basic Components) could be used. These components are:

a - Fragrant
b - Acid
c - Burnt
d - Caprylic (Roguefort Cheese)

These four components could then be rated in intensity on a scale such as that presented earlier and the odor could then be characterized both from an intensity and quality standpoint.

In addition to on-site evaluation, a sample can be extracted from the stack effluent (a 5-gallon container) for possible use by an odor panel under more controlled conditions. This would be a static odor measurement technique rather than the dynamic odor measurement technique performed by field personnel with a Scentometer. This step may avoid interference by inclement weather, e.g., cold or high winds.

Effectiveness of air pollution control equipment in use will include odor evaluation.

4.58 Source Test Report

As with any compilation of technical information, the source test data has little intrinsic value; it must be applied to accomplish a purpose. The data must be reported clearly, and in usable form. A general format for reporting the results of a source test complete with narrative portions are presented (35). The report may not necessarily take this format; for illustration purposes, this type of format is presented.

1. Introduction

    a. Purpose of test
    b. Equipment tested
    c. Name and location of company
    d. Date of test
    e. Operating conditions during test
    f. Names of personnel conducting the test
    g. Company personnel present, especially those in responsible or supervisory positions

II. Summary of Results

    a. Narrative presentation of principal test results
    b. Discussion of significance of results
    c. Description of samples and analysis (odor, smoke determination)

III. Description of Process

- a. Equipment
- b. Operation
- c. Quantities and types of materials

IV. Discussion

- a. Comments on unusual operating conditions of basic or control equipment
- b. Comments on divergences for normal testing procedure with reasons, if any
- c. Other general plant observations, descriptions, or discussion to clarify points not otherwise covered.

V. Sampling and Analytical Procedures

- a. Procedure used (specifications)
- b. Any modification on above procedure

4.59 Summary

The source sampling plan outlined for the industry is a multi-faceted activity. General procedural steps of the plan are outlined in Section 4.52 of the report. A sampling apparatus was recommended, constructed, and field tested as part of the sampling plan. Based on the grab sampling principle, the apparatus was further modified to take a continuous sample. (For complete details of the apparatus see Section 4.25.)

An analytical procedure requisite to the chemical evaluation of effluents and sampling technique was selected. It was concluded that although numerous and sophisticated techniques exist for the precise identification of gaseous compounds the less complex method of total hydrocarbon analysis would suffice for certain segments of the industry. (For complete details of the analytical procedure, see Section 5.4.)

Various sampling locations are pointed out in Section 4.31 and are further illustrated as points of emission in Section 6.0 (Solvent Flow Charts). Data gathered from field visits (Section 3.2) can be used to identify suitable sampling sites for future task work. This information can also be found in Tables 15 through 19 of the report.

To complete the source sampling plan additional elements are discussed. The determination of gas flow rate can be measured and calculated as indicated in Section 4.3 of the report. Section 4.4 illustrates specific measurement of gas temperature, pressure, water vapor and specific gravity of the duct gas.

A method for determining the efficiency of air pollution control equipment in use throughout the industry can be found in Section 4.55. To be as complete as possible the source sampling plan will include visible emission evaluation (Section 4.56) and odor measurement (Section 4.57).

Compilation of technical information for furthur extrapolation will be reported in a source test report as found in Section 4.58 of the report.

5.0 ANALYSIS

5.1 Introduction

Once the sample has been obtained from the effluent stream, it must be analyzed either on-site at a field location or in a laboratory. The analysis becomes a means to an end rather than the end in itself. Information concerning the identity and concentration of pollutants is vital in establishing the nature and the extent of problems related to air pollution and to an evaluation of measures taken to control air pollution (40). Assuming that a valid sample has been obtained and the analytical procedure employed, the actual analysis of the sample becomes the vital link in the measurement cycle. It is essential that those who rely upon results from a particular analysis understand the details of the method that was used so that reasonable interpretations may be made.

5.2 Terminology

5.21 Qualitative and Quantitative Analysis

A qualitative analysis seeks to determine what components are present in significant amounts in a substance or mixture of substances (40). Results of a qualitative analysis are in the form of a statement that the substance of interest is present in amounts above the limit of identification by the analytical procedure used. Terms used to express results can take such forms as "nil", "trace amount", "present" and so forth.

More appropriately, the analytical procedure recommended in the graphic arts industry emission evaluation is a quantitative analysis. This analysis seeks to determine the absolute amounts of the several components present in a gas and condensed phase sample. Results of such an analysis are expressed as concentrations of the components of interest in the sample or original gas stream. These concentrations may be based on weight per weight, weight per unit volume, or volume per volume relationships, and may be expressed as percentages or parts per million (ppm), the latter being especially suitable for air pollution analysis of effluents associated with graphic arts operation.

5.3 Methods of Analysis

Some ten methods of analysis were obtained as a result of the field visits and are listed in Table 25 (Appendix C). These

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methods, as was the case with the methods of sampling presented in Table 21 (Appendix C), may not include all the methods; however, it is felt that the majority of analytical methods employed in graphic arts operations are included. Five of the methods listed in the table are utilized by control agencies and consulting laboratories in the Southern California area and were developed to evaluate components subject to specific air pollution control regulations. For the most part, gas chromatography is widely used in these analytical techniques.

An interesting approach in instrumentation is the method used by Continental Can Company, Inc. (41). A total hydrocarbon analyzer constructed to their specifications by Teledyne Analytical Instruments (San Gabriel, California) is employed. The instrument operates on the hydrogen flame ionization principle, is reasonably portable, and responds linearly over a range of 0 to 10,000 parts per million hydrocarbon. However, the detector is insensitive to oxides of carbon and water and has limited responses to oxygenated carbon compounds. Non-dispersive infrared analyzers must be used to achieve sensitivity with respect to carbon oxides.

The use of a total combustibles analyzer followed by an ultraviolet analyzer (Method 7, Table 25, Appendix C) to record non-exempt hydrocarbons as defined by Los Angeles Rule 66 and San Francisco Regulation 3 represents still another approach.

Finally, an infrared spectrophotometer (Method 6, Table 25, Appendix C), whereby the sample is absorbed in carbon tetrachloride, and the results expressed in terms of parts per million hexane has been utilized in the graphic arts industry (42).

5.4 Analytical Procedure to be Used by GATF

Having examined the several possible analytical techniques with personnel of the Physical Measurements Laboratory of Mellon Institute, two methods of analysis have been selected; one will serve as an alternate approach. Figure 7 (Appendix B) is a schematic diagram of the Cal-Colonial Chemsolve Chromatographic Flame Ionization Analysis. This method analyzes the collected sample in portions; condensibles (that part collected in the trap) and non-condensibles (that part collected in the sampling cylinder bulb). By means of oxidizing and reducing sections, the carbon-containing portions of the sample is converted to methane for ultimate detection by flame ionization. Results reportable by the method are expressed as ppm CO, CO_2, CH_4, and total carbon. Figure 8 (Appendix B) schematically illustrates an alternate method, the Los Angeles APCD Total Combustion Analysis (43). In this method, both the condensible and non-condensible portions of the sample are catalytically oxidized to CO_2 and detected by infrared analysis. The results are similar to those outlined in the previous method.

The Cal-Colonial analytical method which involves oxidation of all components to carbon dioxide followed by reduction to methane was selected because of the following considerations:

1. The scale of sample size used is compatible with conventional gas chromatographic components.
2. The hydrogen flame detector is not flow dependent, whereas the non-dispersive infrared detector is flow dependent.
3. Although the sensitivity of the flame detector is to some extent a function of compound structure, the prior reduction of all sample components to methane can provide a true carbon content analysis.

5.5 Review of Emission Measurement Instrumentation

Of particular interest to the graphic arts industry is a group of instruments known as primary sensors (44). These devices are used to measure both physical and chemical variables. The primary physical variables measured are temperature, pressure, flow rates, etc., with these variables being readily measured by many commonly accepted devices such as temperature controllers, pressure gages, flow rate meters and so forth. This type of primary sensor is commonly recognized by management and plant personnel. However, the other broad category of primary sensors, those dealing with the measurement of chemical composition variables are not as well known and understood; consequently, they warrant selective treatment. These types of sensors are often referred to as on-stream or on-line analyzers.

5.51 Infrared Analyzer

A primary analyzer having many applications to graphic arts is the infrared instrument (44). This type of analyzer is usually used to measure the concentration of a single chemical component.

This is done by measuring the extent of infrared absorption within a specific narrow wavelength band that is strongly absorbed by and characteristic of the component being determined. Infrared analyzers are useful in measuring trace components; however, since a single instrument is designed to measure only one component, two such instruments are necessary to measure two components in a single process stream. Infrared analyzers are widely used to measure the concentration of such gases as carbon dioxide, carbon monoxide, nitric oxide, and water vapor, as well as vaporized hydrocarbons and other substances that are liquids at room temperature. They cannot be used to determine oxygen, hydrogen and other diatomic gases which do not absorb infrared energy. Another problem with infrared analysis is that complete identification of (hydrocarbon) compounds is not possible. For example, it cannot accurately measure butane in propane because their infrared absorption bands are so close together. In this particular case, gas chromatography has performed the separation quite satisfactorily, and the separated components could be analyzed independently.

5.52 Ultraviolet Analyzer

This type of analyzer, also used in analytical work associated with the graphic arts industry, operates on the same principle as infrared (44). The basic difference is in the wavelength or frequency of radiation employed. Both instruments have many of the same advantages and disadvantages. Ultraviolet radiation, unlike infrared, cannot be used to measure saturated hydrocarbons although both types of radiation can be used to measure unsaturated hydrocarbons and aromatics (44). Ultraviolet devices are now being used to measure atmospheric concentrations of photochemically reactive hydrocarbons particularly in the Los Angeles area. Compared to infrared instruments, ultraviolet analyzers generally are able to measure substances more selectively.

5.53 Gas Chromatography

A gas chromatograph assembly usually consists of a sampling system, (which obtains the sample and prepares it for analysis), a chromatographic column, temperature controller, a detector, and a recorder (44). A suitably prepared gas or vaporized liquid sample is admitted to the column as a "plug" and swept through the column by a carrier gas such as helium. The column is packed with an inert solid frequently coated with a nonvolatile absorbing liquid. The column temperature is increased at a programmed rate. Sample components leave the column at different rates, depending on the absorption-desorption of the effluent fractions at a given temperature, within the liquid held on the packing material. Thus, each component emerges from the column separately. The least soluble or low-boiling component leaves first; the most soluble or highest boiling material last. The identity of the component is established by comparing its retention time on the column with the time required for a calibrated sample to emerge from the column. The concentration of the substance is determined by the area under the peak, measured by the detector output and registered on a recorder. The detector most commonly used is a hot-wire thermal conductivity cell. Increasingly, however, flame ionization detectors are being used for high-sensitivity hydrocarbon analyses. Unlike infrared or ultraviolet spectrometers which record the absorption spectrum of the whole sample, gas chromatographs segregate sample components for identification by the detector or alternate analytical techniques when required. Gas chromatographs are widely used to measure saturated and unsaturated hydrocarbons, glycols, organic acids, oxygen, nitrogen, hydrogen, and so on.

The two types of detectors used in gas chromatography are thermal conductivity and flame ionization.

A. Thermal Conductivity

This type of sensor or detector cell is used to measure the output gases from a gas chromatograph.

These cells work on the principle that different gases conduct heat at different rates. The thermal conductivity of a gas mixture, which depends on its chemical composition, is measured by the extent to which an electrically heated wire is cooled. The cooling is measured by a decrease in the wire's electrical resistance. This technique is especially useful in analyzing for one component in a simple mixture of only two or three gases, and works particularly well if the component being measured has much greater thermal conductivity than do the other gases present. Thus, small changes in the concentration of the component being measured will have a relatively large effect on the mixture's overall thermal conductivity.

B. Flame Ionization

This type of sensor or detector is used for high sensitivity hydrocarbon analysis in gas chromatography and is used in the total hydrocarbon type analyzer.

These cells operate on the principle of ionization which hydrocarbons undergo when passed through a hydrogen flame. The ionized hydrocarbons are detected with a sensitive electrometer which activates a meter or a strip chart recorder. The detector literally counts the carbon atoms that pass through the flame, and thus is often referred to as a "carbon counter." The detector, however, is insensitive to oxides of carbon and water and has limited sensitivity for oxygenated carbon compounds. Although detector insensitivity to oxides of carbon prevents complete appraisal of the stream gas, direct reading instrumentation specific for the oxides of carbon (infrared instruments) is available as complementary apparatus.

5.54 Liquid Chromatography

Liquid chromatographs have not been applied to date to pollution problems in the graphic arts industry. Liquid chromatography is generally used only where the use of gas chromatography would be difficult or impossible (44). This would include the analysis of substances that are non-volatile at reasonable temperatures or, if volatilized, would decompose at the required elevated temperatures. Liquid chromatographs frequently use refractometers as detectors instead of the thermal conductivity cells used in gas chromatography. They sometimes require high-pressure pumps (supply pressure of 300 psi) and sealing mechanisms and when compared to gas chromatographs, liquid chromatographs are also more expensive.

5.55 Moisture Analyzers

The use of moisture analyzers is beginning to make its way into the graphic arts field. There are a variety of methods available (44). One device is based on water vapor absorption by a phosphorous pentoxide film supported by two rhodium electrodes. Another determines water content of gases by measuring the frequency with which a quartz-crystal oscillator coated with hygroscopic material vibrates in the MHz (megahertz) range. A third method measures the heat generated when moisture is adsorbed on a solid desiccant (later to be desorbed). The temperature of the desiccant, determined by thermocouples, is a function of the moisture concentration in the gas mixture. Finally, a recent development in moisture-measuring devices is one that measures the extent to which infrared radiation of 1.93μm (micro-meter, 10^{-6}m) wavelength is absorbed by the water present in a moist material. (Recent application of this method is in determining during manufacturing the moisture content of paper.)

5.6 Available Field Type Instrumentation

5.61 Introduction

The following compounds lend themselves to continuous analytical field monitoring type instrumentation which is currently marketed by several instrumentation companies: sulfur dioxide, nitrogen oxides, oxidants, carbon monoxide, carbon dioxide, hydrocarbons, and fluorides.

Of particular interest to the graphic arts is a class of pollutant termed "hydrocarbons." Although used loosely in the past to include other organic solvents, the federal government in issuing its "Air Quality Criteria" document (47) has defined "hydrocarbons" as containing only the elements hydrogen and carbon and an "organic solvent" as one which may contain in addition to hydrogen and carbon, one or more of the following elements: oxygen, nitrogen, sulfur and halogens. The above document includes both hydrocarbons and organic solvents.

5.62 State-of-the-art Instrumentation

The present state-of-the-art in the are of field type instrumentation applicable to "organic solvents" is based on the principle of hydrogen flame ionization of carbon atoms (Section 5.53). (An instrument has been manufactured which colorimetrically measures aldehydes (defined as an organic solvent) but little is known of its performance.)

In order to attempt to analyze specific organic contaminants, a gas chromatograph and/or infrared absorption spectrophotometer must be employed. There exists a modified ASTM qualitative and semi-quantitative analysis of recovered organic solvents (48) which is carried out by column chromatography.

This method of analysis provides an estimate of the ratios of saturates, olefinics, aromatics and oxygenates present.

The gas chromatograph equipped with a hydrogen flame detector remains the basic instrument for determining total organics. Under defined conditions, it can be used for discrete samples providing a versatile method for combined quantitative and qualitative analysis of hydrocarbons and organic solvents. The complete identification of each and every component in an effluent sample taken from a graphic arts process remains difficult if not impossible.

5.63 Field Type Instrumentation

The industry needs direct reading instrumentation for performance appraisal of its process relative to emission levels and of its emission control equipment. There is currently available a direct reading, readily portable, combustible gas analyzer manufactured by Johnson-Williams Products of Mountain View, California. This particular version referred to as Compensated Model SSP (No. 503-005) is used by the San Francisco Bay Area Air Pollution Control District inspector in field evaluating a process in lieu of a more formal source testing procedure. In principle, it depends on the heat of combustion of the combustible fraction of the sample and according to the manufacturer is recommended for all services except those where methane, leaded gasoline vapor or chlorinated hydrocarbons are frequently encountered. The instrument is battery driven and provides a unit of measurement expressed in ppm concentrations.

In use throughout various control agencies is a Universal Tester, which is based on colorimetric analysis of specific gases and consists of a variable orifice/variable volume piston pump for sampling, filters and glass detector tubes. The detector tube contains a chemical reagent which absorbs and reacts with the gas or vapor being analyzed. A color stain is produced which varies in length according to the concentration of the material being measured.

The length of stain is measured against a calibration chart furnished with each box of tubes. Some fifty different gas detector tubes are available. Of interest to the graphic arts industry are the following: carbon monoxide, aromatic hydrocarbon, unsaturated hydrocarbon and aldehydes. There are several manufacturers of this item all of which claim that tests have proven their tester to provide both reproducible and accurate results. This tester can be operated by plant personnel and requires little training in operation.

5.7 Existing Graphic Arts Industry Emission Data

A limited amount of testing has been performed on graphic arts processes with the result being little reportable data. A majority of the so-called field tests has, of course, been confined to the Southern California area and thus available emissions data has been been reported along those regulatory lines. One such effluent test was conducted by a consultant on a web offset press complete with dryer and no control equipment at several stated conditions (1-4 below):

1. Test run on coated paper. Inks were run on approximately 30" web width with approximately 60% coverage which included 4-color process printing on one side, a printing speed of 1500 impressions per minute, oven temperature of 300°F, exhaust temperature of 132°F and exhaust rate of 4500 scfm.

2. In order to evaluate the emissions that were related to the paper being used, a sample was taken of the effluent from the running of paper (glossy stock) only. No ink was used.

3. In order to further evaluate the emissions that were related to the paper (news stock as opposed to glossy paper), a sample was taken of the effluent from the running of this type of paper only. No ink was used.

4. Test run on news stock. Inks were run on approximately 30" web width with approximately 60% coverage which included 4-color process printing on one side, a printing speed of 1500 impressions per minute, oven temperature of 300°F, exhaust temperature of 132°F and exhaust rate of 4500 scfm.

   Table 26 is a summary of values found for each set of conditions.

TABLE 26

EFFLUENT TESTS ON WEB OFFSET PRESS: NO CONTROL EQUIPMENT

Product	Test Conditions 1	2	3	4
CO^a	55	36.5	7.3	55
CH_4^a	18	9	9.1	18
CO_2^a	3010	2970	3180	2850
Other^a	263	180	73	250
HC^b	1.03	0.703	0.287	0.985
C^c	0.279	0.190	0.077	0.266

a. ppm
b. Hydrocarbons, lb C/cu ft x 10^5
c. lb/hr

The Los Angeles Air Pollution Control District has been performing tests of equipment for compliance with Rule 66 for several years. Table 27 (Appendix C) shows the range of values found from hundreds of individual analyses of industrial emissions (45). The emission rates (uncontrolled) correspond to a range of less than one pound to almost 40 pounds of carbon per hour. Interesting to note is the fact that due to the wide variations in temperature, ventilation and circulation requirements in the design of drying and baking ovens for the various processes, the L. A. APCD authorities conclude (45) that no numbers can be given for exhaust volumes or concentrations as "typical" or "average" for these operations. In addition data compiled has indicated that afterburner control efficiencies are greater when effluents contain high organic concentrations. With few exceptions, the minimum operating temperatures for well-designed afterburners (90 percent control of the organic carbon) have been found to be in the range of 1350-1500°F.

Limited reportable emission data from areas of the country other than the Southern California area indicates the following:

(a) Effluent tests on web offset press complete with dryer and direct flame afterburner:

	Before Control Equipment	After Control Equipment
CO	33	16.7
CO_2	4050	23000
Methane	–	–
Residual Organics	630	25

The gas samples were analyzed using a gas chromatographic separation, oxidation and reduction techniques. The results were reported in parts per million by volume as carbon (C_1). The incinerator temperature during the test was $1200^{\circ}F$.

(b) Effluent tests conducted on a web offset press complete with dryer and catalytic combustion control equipment.

CO	Non-discernible	–
CO_2	1.0%	3.0%
O_2	19.0%	17.0%
Total Hydrocarbon	667 ppm	33 ppm

The gas samples were analyzed by use of an Orsat apparatus and by gas chromatography to determine total hydrocarbon. The incinerator temperature during the test was $900^{\circ}F$.

(c) Approximately 25 to 30 effluent tests were performed by a consulting laboratory using gas chromatographic analysis. In one test, in which the web offset press was run without ink, a total of 7 ppm of hydrocarbon was found. With ink, this figure increased to 18 ppm of unburned hydrocarbon of which only 3 ppm were C_{11} or higher. Another test was made using newsprint stock (uncoated) and a highly coated sheet. On newsprint a total of 14 ppm of hydrocarbon was detected in the exhaust, against 7 ppm on the coated sheet. In both cases no C_{11} or higher hydrocarbons were found.

(d) Several theories were advanced relative to the nature of the effluents in the exhaust from printing and metal decorating operations while conducting the field visits and are so listed:

(1) Exhaust contains high boiling hydrocarbons (above C-10), aldehydes and alcohols (46). Aldehydes are a suspected contributor to eye

irritation and odor. A contradictory theory indicates waxy compounds (namely, organic acids) are the odor offenders.

(2) Analysis of the effluent stream should reveal a moisture to hydrocarbon ratio on the order of magnitude of 30 to 1 ppm.

(3) Several investigative findings suggest the presence of acrolein (possibly from the paper) as well as formaldehyde in the effluent stream and these could be contributors to the odor problem.

(4) In addition, consultants have suggested that ketones could be the source of offensive odors in the metal decorating operation.

6.0 SOLVENT FLOW CHARTS

Flow charts have been drawn to show points of organic emission from various printing processes. The processes which are the largest contributors are considered in the greatest detail and other printing processes which contribute less are presented in a simpler form. Certain processes with a relatively small volume of business, or processes which are not applicable for other reasons are not shown.

The six processes which were studied for this report are offset lithography, letterpress, metal decorating, gravure, flexography and screen printing. The inks and coatings used in these processes are the major source of organic emissions. Heatset inks, used in lithography and letterpress, generally contain 30 to 40% solvent and at least half of this solvent is removed in the dryer. Gravure and flexographic inks usually contain about 60% low-boiling solvent, and most of this is removed by the drying process. In metal decorating, the principal source of the organic emissions is the protective coatings put under and over the ink, rather than the ink itself. Screen process printing uses many types of inks and paints, some of which are high in volatile solvent; however, total production is the smallest of the six processes mentioned.

Many processes were not represented because of the small volume of production they represent. In this category are direct lithography, which transfers ink from the plate directly to the paper, and collotype which is similar to lithography and stenciling. Offset letterpress, or "dry offset" is not very common and was not included either. Office copying or duplicating is not considered to be part of the industry. Electrostatic printing, or xerography, and thermographic printing similarly do not contribute to emissions. Finally, steel die engraving and embossing are low volume operations using very viscous, low solvent inks.

Web or, more properly, strip coating in the metal decorating industry is not included in this section because it is not considered to be a division of the graphic arts industry. Usually no printing is done in strip coating and the coatings used are similar to paints rather than inks

There are many sources of emissions from specific processes which were not shown on the flow charts although some information was acquired during the field visits. For example, inorganic material, solids, or any materials which are not emitted from the building are not considered to be a part of the organic emission study. This includes fumes from various platemaking processes, anti-setoff spray powder and bindery paper dust, among others.

However, the fate of ink solvents, alcohol from lithographic fountain solutions and wash-up solvents is always indicated on the flow charts.

In addition, the dryer-equipped processes in some cases may exhaust pyrolized derivatives of ink solvents, paper components and ink vehicles, as well as CO, CO_2 and unburned fuel gas. Emission points for all these materials are noted on the diagrams.

Emission points may be anywhere in the printing process, although the type of emission may differ at each point. Alcohol is emitted mainly from lithographic fountain solutions and from the litho plate surface and also from certain flexographic inks. Ink solvents are emitted from the entire process in flexo, gravure and certain screen printing processes, but essentially only from the dryer in processes using heatset inks. Coating solvents are emitted from the roller coater in metal decorating. However, the main emission point is the oven exhaust. Very little solvent is contained in the cooling zone exhaust. Smoke from pyrolized or volatilized organic material is emitted from the dryer and chill rolls when heatset ink is dried. Small amounts of ink mist are produced on high speed presses, particularly letterpress. Finally, combustion products such as CO, and unburned fuel gas, are emitted from fume burners and from direct-fired dryers. However, no emission of combustion products is shown when heat is transferred to dryer air indirectly as when steam radiators are used.

In designing the various printing processes, it should be remembered that a particular dryer or piece of fume control equipment is not necessarily specific for only one process. There are certain design criteria, involving temperature, flow rate, and concentration and composition of the exhaust stream in question. For example, a heat exchanger can be used to conserve heat almost anywhere in the process. The efficiency depends on flow rates and temperature differences, but because of the high cost, the break-even point for heatset lithography and letterpress lies somewhere between 5000 and 10,000 standard cubic feet of gas per minute to be heated. Rotary heat exchangers can be used anywhere, but are less desirable for recovering heat from a fume incinerator exhaust than from other streams. This design allows some bypass of gases from the cold inlet to the hot side if the pressure difference is in this direction.

Similarly, either a catalytic or a direct flame incinerator can be used for removing solvent fumes from heatset ink emissions, where the process is letterpress or lithography. Because of the lower operating temperature, the catalytic installations would be less likely to have a heat exchanger installed, but such an installation is possible. It is also possible to use catalytic and thermal units in the same system.

Carbon adsorption is used for gravure operations where a single solvent system is used. However, where several solvent systems are used, adsorption with subsequent distillation of the condensed solvent is necessary. Adsorption can also be used for flexographic processes using organic solvents, although no installation was observed in the field visits. The economic advantage of solvent recovery and re-use as opposed to the use of incineration for gravure and flexo effluents can best be described as questionable depending upon the complexity of the solvent mix used and its capability of re-use. Use of incineration equipment with a heat recovery system on gravure effluent has been accomplished and is a possibility when considering selection of control equipment. Adsorption, on the other hand, is not recommended for heatset ink systems because of the presence in the exhaust of tarry degradation products which are difficult to remove from the activated carbon.

These flow diagrams are intended to provide a schematic illustration of all important printing processes. They are arranged according to the four types of image carriers and are subdivided according to the type of ink or coating used or differences in equipment or procedure. Where possible, web widths, paper and ink feed rates and dryer and incinerator operating conditions are given to establish a basis from which organic emission rates can be estimated. The ink usage figures are based on coated paper, with a moderate amount of ink coverage of about 100% per side. (The maximum for four colors is 400%.) The web widths used are based on existing equipment but do not represent average widths, since sizes vary extensively for each process. The 38" width would be representative for web offset lithography, but narrow when compared to the largest web offset presses or web letterpresses used in publications printing. The 63" gravure web width in Figure 22 is normal for older presses, although a few newer presses take much wider webs. Flexographic printing of carton stock or foils is done with a 44" web, but narrower widths are also common.

The effluent control systems shown are based on existing systems, but are not necessarily typical of the industry. Indeed, during the study, no single control system could be identified as typical for a given commercial printing process, and several processes do not require effluent control. Web letterpress and web offset control installations were found generally to be more simple than the systems shown and usually consisted of one oxidation unit per press, with no heat exchangers. Although operating conditions are described in the larger diagrams for individual heat exchangers and oxidation units, the illustrated combination of units may be similar to only one or two existing installations.

The description of individual process diagrams follows. In addition, Tables 28 to 31 (Appendix C) give a brief description of the printing processes and the related air pollution problem.

6.1 Offset Lithography

The lithographic process transfers ink from an image area which is essentially at the same level as the non-image area. The non-image area is wet by water only and the image area is wet by ink only. Water is transferred to the plate first, followed by the ink

Offset lithography usually employs curved metal plates mounted on a cylinder press. The water used for dampening the plate may contain 15 to 30% isopropanol, and if the Dahlgren or several other dampening systems are used, isopropanol is required. After ink is transferred to the plate, the ink is transferred from the image to a rubber surface on the blanket cylinder, which in turn transfers the ink to the paper. When a web or continuous roll of paper is used, this process is commonly called web offset.

6.11 Web Offset Publication

In Figure 9, a 38" wide web traveling at 1000 feet per minute enters a press. When the blanket-to-blanket press configuration is used the paper is fed between two blankets and two different images are printed simultaneously on the two sides of the sheet. After passing through several printing units, the two complete images are printed on both sides and the web enters the dryer. Leaving the dryer,

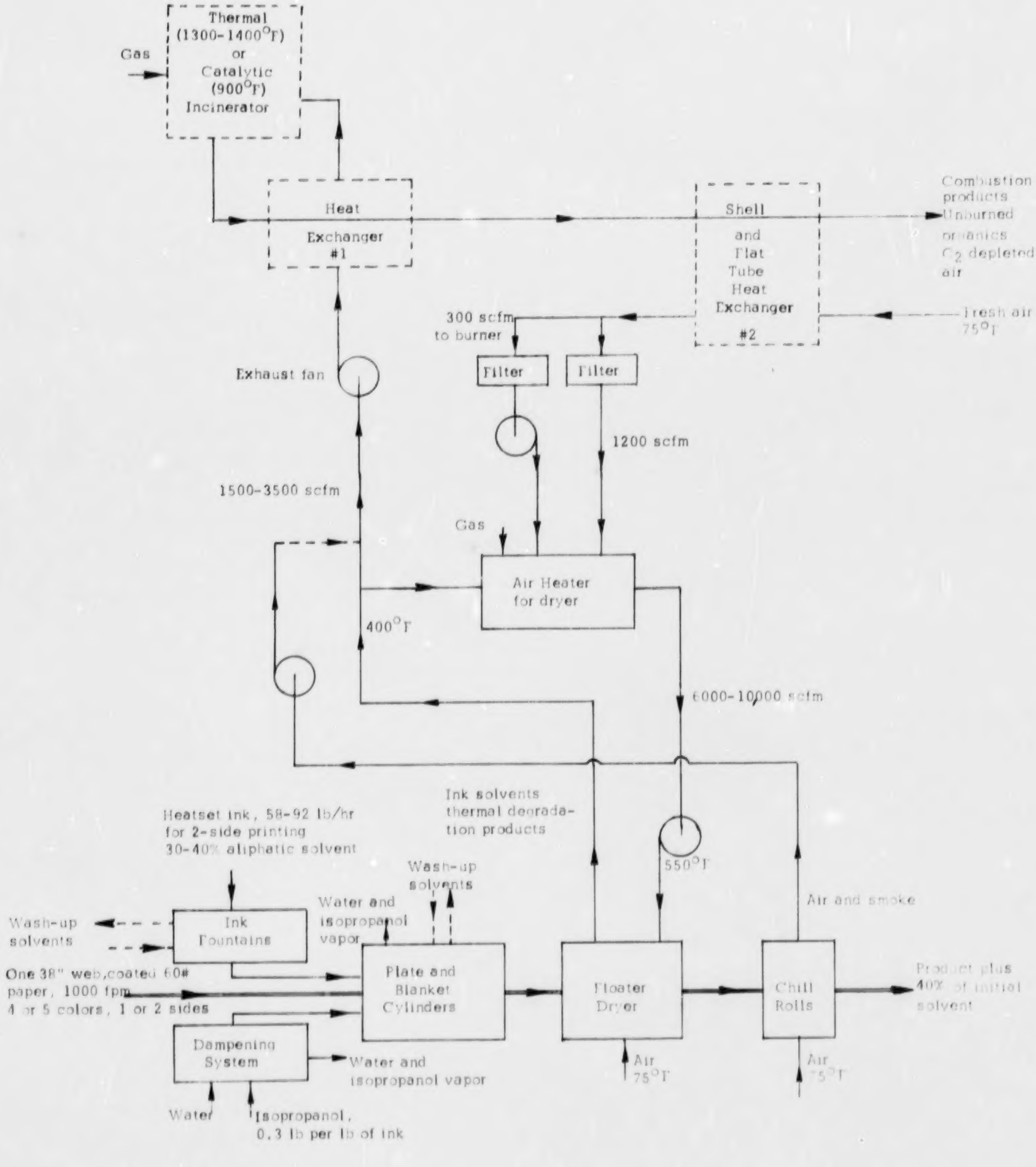

Gas
Thermal
(1300-1400°F)
or
Catalytic
(900°F)
Incinerator
Heat
Exchanger
#1
Shell
and
Flat
Tube
Heat
Exchanger
#2
Combustion
products
Unburned
organics
O_2 depleted
air
Fresh air
75°F
300 scfm
to burner
Filter
Filter
Exhaust fan
1200 scfm
1500-3500 scfm
Gas
Air Heater
for dryer
400°F
6000-10000 scfm
Ink solvents
thermal degrada-
tion products
550°F
Air and smoke
Heatset ink, 58-92 lb/hr
for 2-side printing
30-40% aliphatic solvent
Wash-up
solvents
Water and
isopropanol
vapor
Wash-up
solvents
Ink
Fountains
One 38" web, coated 60#
paper, 1000 fpm
4 or 5 colors, 1 or 2 sides
Plate and
Blanket
Cylinders
Floater
Dryer
Chill
Rolls
Product plus
40% of initial
solvent
Dampening
System
Water and
isopropanol vapor
Air
75°F
Air
75°F
Water
Isopropanol,
0.3 lb per lb of ink

Figure 9
Web Offset, Publication
(Optional equipment shown dotted - Letterpress and offset incineration systems are interchangeable)

the paper passes over chill rolls and is then ready for folding, cutting or other finishing operations.

It is also possible to feed the paper between a blanket roll and an impression cylinder, printing it on only one side, although this is more usual in sheet-fed operations. Another configuration consists of several blanket rollers and a common impression cylinder. In either case, when the paper is printed only on one side, the dryer exhaust rate may be as much as 30% less than when both sides are printed. A tunnel dryer may be used when a web is printed on one side only and is the only dryer that can be used when both sides of the web are printed simultaneously such as in blanket-to-blanket printing. Conversely the steam drum is not applicable to the drying of blanket-to-blanket printing because of the problem of wet ink contact with the steam drum surface.

Optional additions to the drying process are shown with dotted lines. The smoke and air from the chill roll area is shown entering the dryer exhaust. However, it could probably be added to the dryer recycle as part of the makeup air or simply be exhausted without any correction.

The incinerator and two heat exchangers are shown in one possible arrangement. Either or both heat exchangers may be eliminated. If a catalytic incinerator and only one heat exchanger is used, the greater efficiency will be obtained using exchanger No. 2, rather than No. 1, simply because of the greater temperature difference between the two streams.

6.12 Web Offset, Newspaper, Business Forms

Figure 10 is a web offset operation printing newspaper or business forms. No dryer or air pollution control equipment is used because the ink contains very little solvent, somewhat porous paper is generally used, and the coverage is much less with text than with pictorial process color work. Isopropanol may be used in fountain solutions, but this is probably not common.

The web is shown operating at 500 feet per minute. Since this operation frequently involves short runs and small shops, a low operating rate was used.

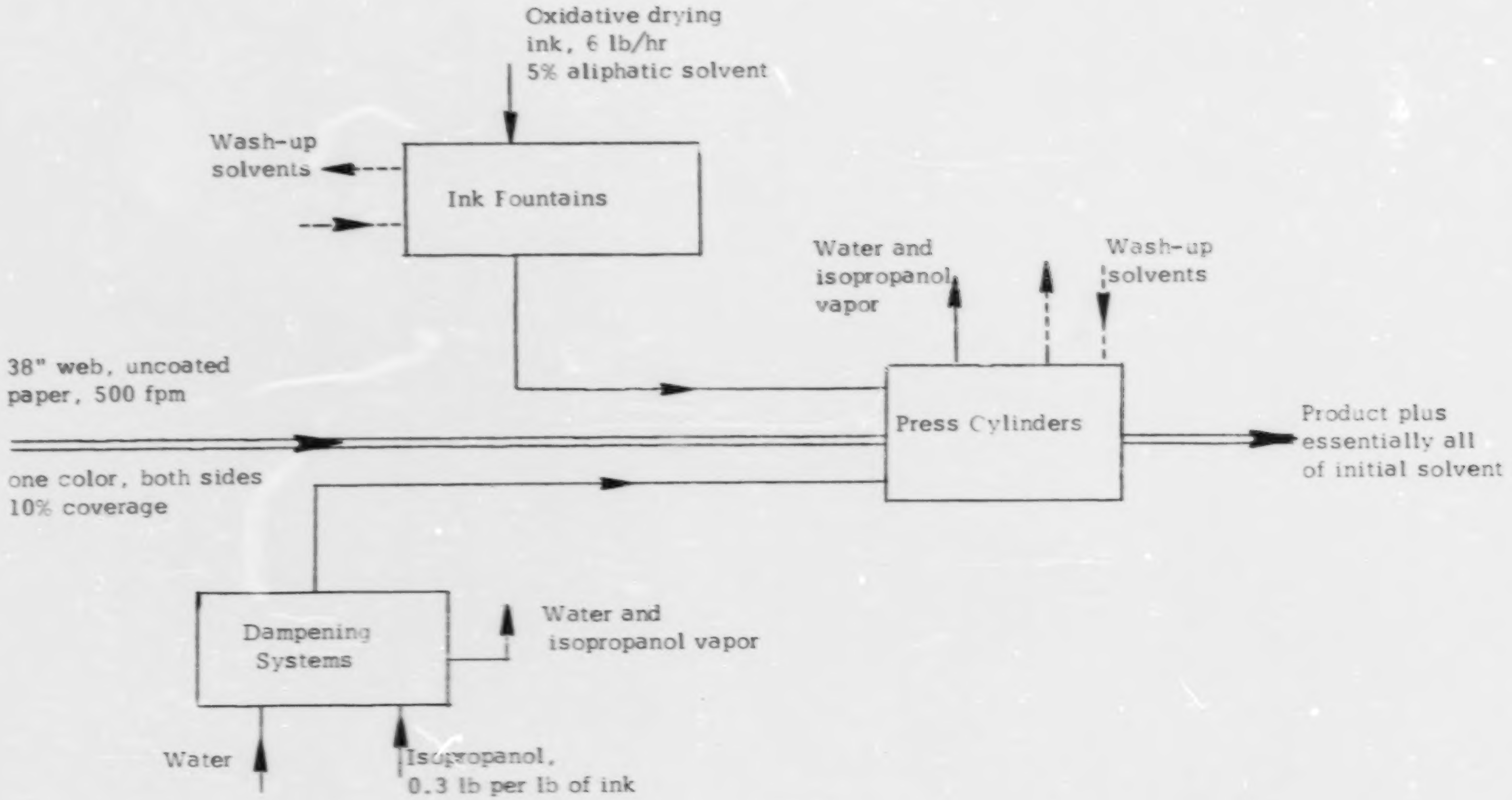

Oxidative drying
ink, 6 lb/hr
5% aliphatic solvent
Wash-up
solvents
Ink Fountains
Water and
isopropanol
vapor
Wash-up
solvents
38" web, uncoated
paper, 500 fpm
Press Cylinders
Product plus
essentially all
of initial solvent
one color, both sides
10% coverage
Dampening
Systems
Water and
isopropanol vapor
Water
Isopropanol,
0.3 lb per lb of ink

Figure 10

Web Offset, Newspaper, Business Form

6.13 Sheet-fed Offset

Figure 11, Sheet-fed Lithography, indicates the possibility of passing the printed sheet under a small flame as it is delivered from the press. Sheet-fed lithography uses either coated or uncoated paper, with low solvent, oxidative drying inks. The use of isopropanol in fountain solutions and printing on one side per unit are more common than in the perfecting web processes. Presses can consist of one, two or more printing units. Sheets are shown fed at a rate of 4000 per hour. Ink usage is much less than in the web offset publication example because of the lower feed rate, and also because only one side is being printed.

6.2 Letterpress

In this process the ink is transferred to the paper from the image surface, which is raised slightly relative to the non-printing surface of the plate. Originally all letterpress was done with a flatbed image carrier and the image was the original hand set type. In much current practice, however, the image is transferred to a mat which can be curved. Then a cylindrical plate is made from the curved mat.

Although the plate is usually type metal, some success has been achieved with flexible plates of plastic composition which can be formed flat and then wrapped around the cylinder of the press. Flexography, which is considered separately under Section 6.5, is actually a form of letterpress done with rubber plates. This process uses inks containing alcohol or alcohol/aliphatic solvents. The printing of pocketbooks using rubber plates and high-boiling hydrocarbon solvents in the ink is sometimes referred to as letterpress, but is considered under flexography for the purposes of this report.

In the letterpress configuration, the paper is printed on one side at a time. If four or five colors are to be printed on both sides, a split web can be used. After the paper web passes through the press and one dryer box, it is turned over and returned to the same press where it runs beside the first pass on the same cylinders. (This is called double ending.) Then the web on the second pass goes through a second dryer box. The alternative to this is using two presses in tandem.

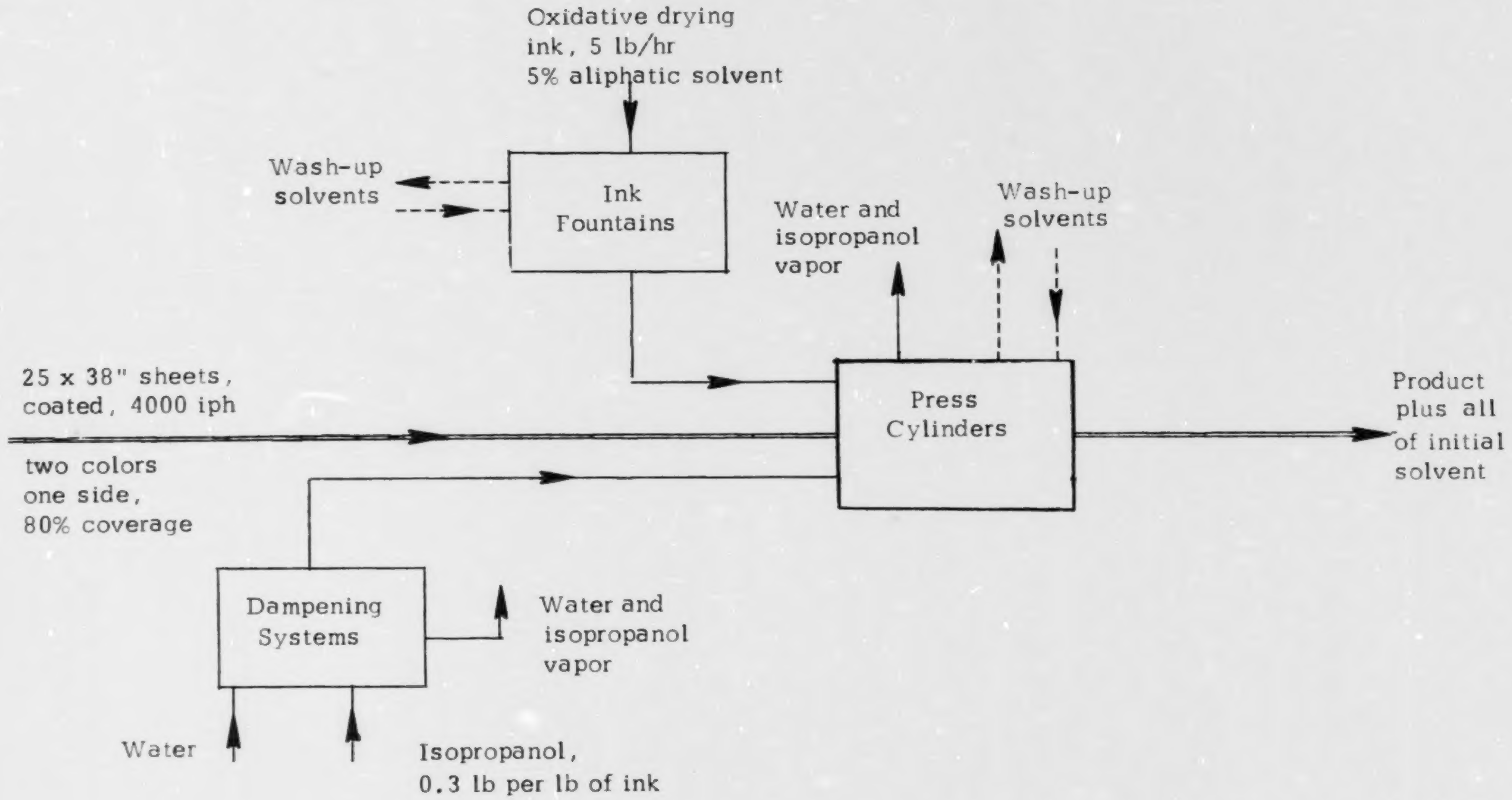

Oxidative drying
ink, 5 lb/hr
5% aliphatic solvent
Wash-up
solvents
Ink
Fountains
Water and
isopropanol
vapor
Wash-up
solvents
25 x 38" sheets,
coated, 4000 iph
Press
Cylinders
Product
plus all
of initial
solvent
two colors
one side,
80% coverage
Dampening
Systems
Water and
isopropanol
vapor
Water
Isopropanol,
0.3 lb per lb of ink

Figure 11

Sheet Fed Offset

6.21 Web Publication Letterpress

Figure 12 is shown with an unusually narrow web for this application, so that some comparison with web offset can be made. In this case the increase in web speed from 1000 to 1500 feet per minute more than triples the recommended exhaust rate for two-side printing while a one-third cut in this rate is made because only one side is printed. This has resulted in a doubling of the air flow rates relative to Figure 9, Web Offset Publication.

The flow diagram differs from the web offset diagram because no dampening solution is used. However, wash-up solvents are still used on the press. Some air enters the dryer box where the web enters and exits to prevent emission of smoke from these openings. Air also enters the chill roll hood and the burner section of the dryer and may enter at any gas burner although the incinerator sometimes uses only the exhaust air from the dryer. All air and organic emissions are from the dryer unless incineration equipment is used, in which case the only exhaust is from the incinerator.

In a few cases a catalytic incinerator has been installed in the recycle line of the dryer, as shown. This would not necessarily eliminate the need for another incinerator on the dryer exhaust. Two heat exchangers are shown in the incinerator output line. Either exchanger No. 1, or both No. 1 and No. 2 may be eliminated. A rotary heat exchanger may be used either in location 1 or 2, or at neither location. If used at location 1, however, there is a possibility that there will be some leakage of fumes to the exhaust side from the input side of the incinerator.

6.22 Web Newspaper Letterpress

Figure 13 is a schematic diagram for a large letterpress newspaper. The only material emitted from this process is the relatively inert ink mist and paper dust. The amounts emitted are only noticeable in very large installations and can be removed by the air conditioning system. The diagram shows that filters can be placed in ducts located over the presses to remove some of the ink mist and paper dust.

6.23 Sheet-fed Letterpress

Figure 14 describes the very simple sheet-fed letterpress operation. The possibility of passing the printed sheet under a series of small

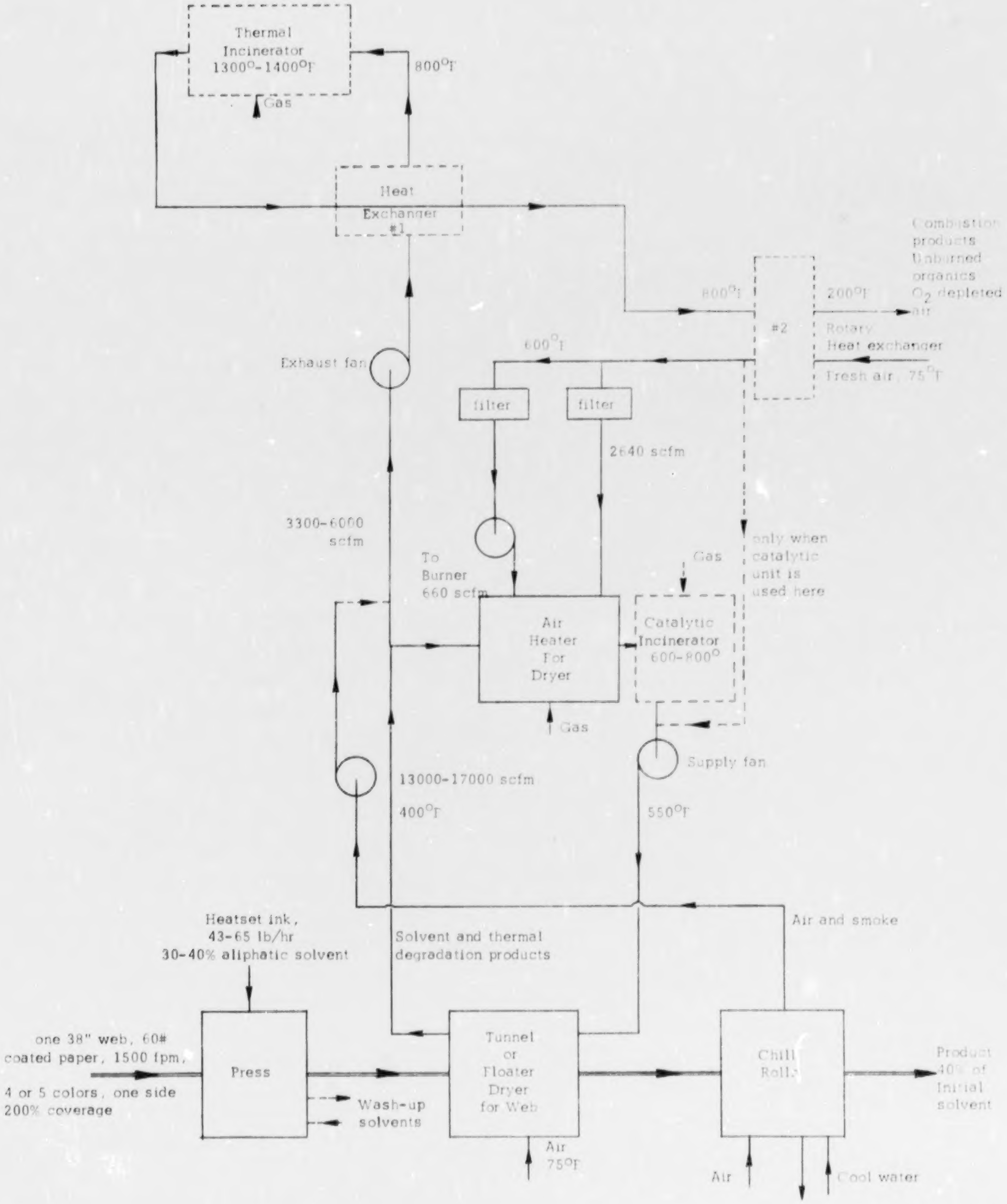

Thermal
Incinerator
1300°-1400°F
Gas
800°F
Heat
Exchanger
#1
Combustion
products
Unburned
organics
O2 depleted
air
800°F
#2
200°F
Rotary
Heat exchanger
Fresh air, 75°F
600°F
Exhaust fan
filter
filter
2640 scfm
3300-6000
scfm
To
Burner
660 scfm
Gas
only when
catalytic
unit is
used here
Air
Heater
For
Dryer
Catalytic
Incinerator
600-800°
Gas
Supply fan
13000-17000 scfm
400°F
550°F
Heatset ink,
43-65 lb/hr
30-40% aliphatic solvent
Solvent and thermal
degradation products
Air and smoke
one 38" web, 60#
coated paper, 1500 fpm,
4 or 5 colors, one side
200% coverage
Press
Wash-up
solvents
Tunnel
or
Floater
Dryer
for Web
Air
75°F
Chill
Rolls
Product
40% of
Initial
solvent
Air
Cool water

Figure 12

Web Publication Letterpress
(Optional equipment shown dotted - letterpress and offset incineration systems are interchangeable)

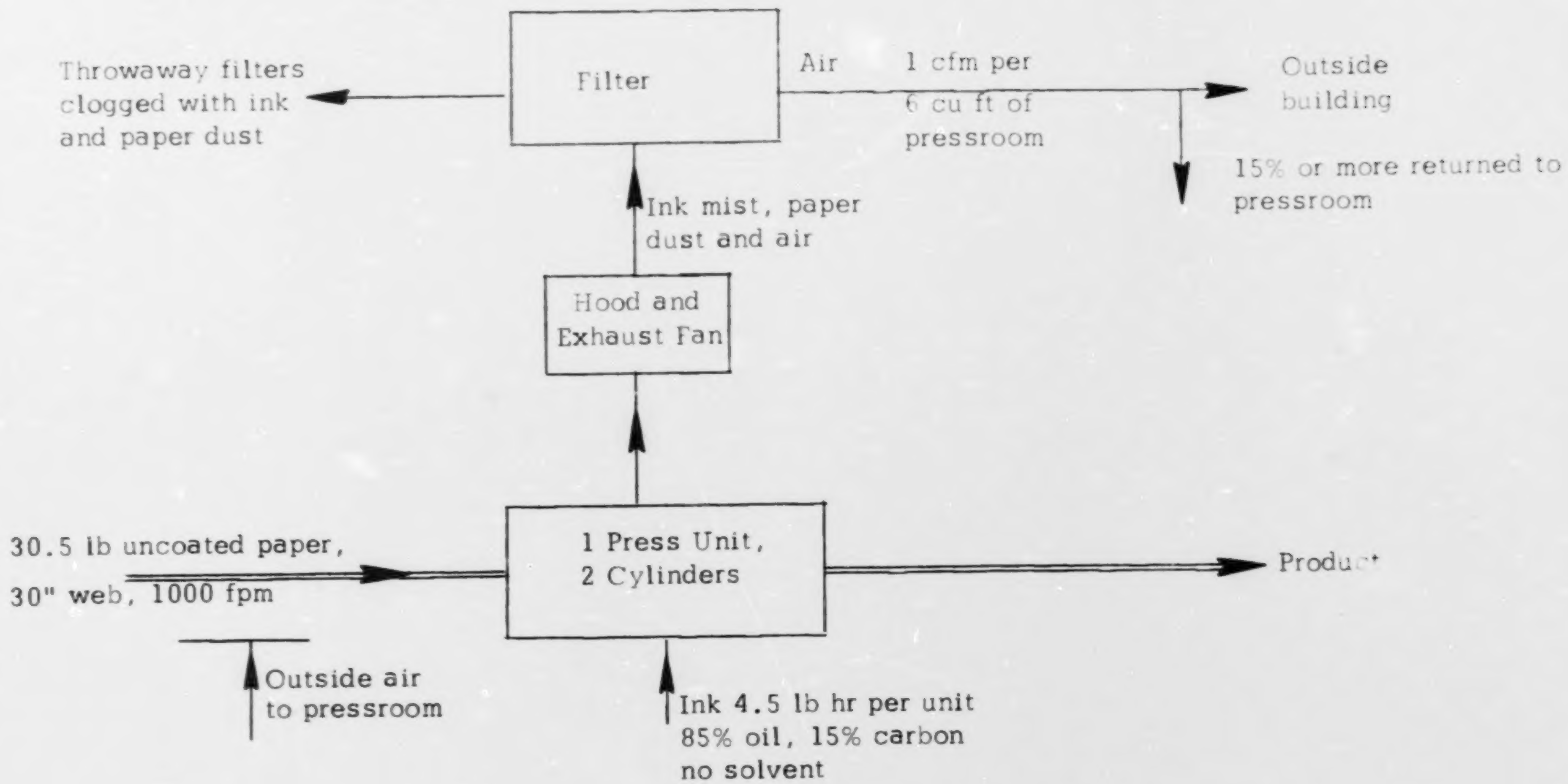

Filter
Throwaway filters clogged with ink and paper dust
Air
1 cfm per 6 cu ft of pressroom
Outside building
15% or more returned to pressroom
Ink mist, paper dust and air
Hood and Exhaust Fan
30.5 lb uncoated paper, 30" web, 1000 fpm
1 Press Unit, 2 Cylinders
Product
Outside air to pressroom
Ink 4.5 lb hr per unit 85% oil, 15% carbon no solvent

Figure 13

Web Newspaper Letterpress

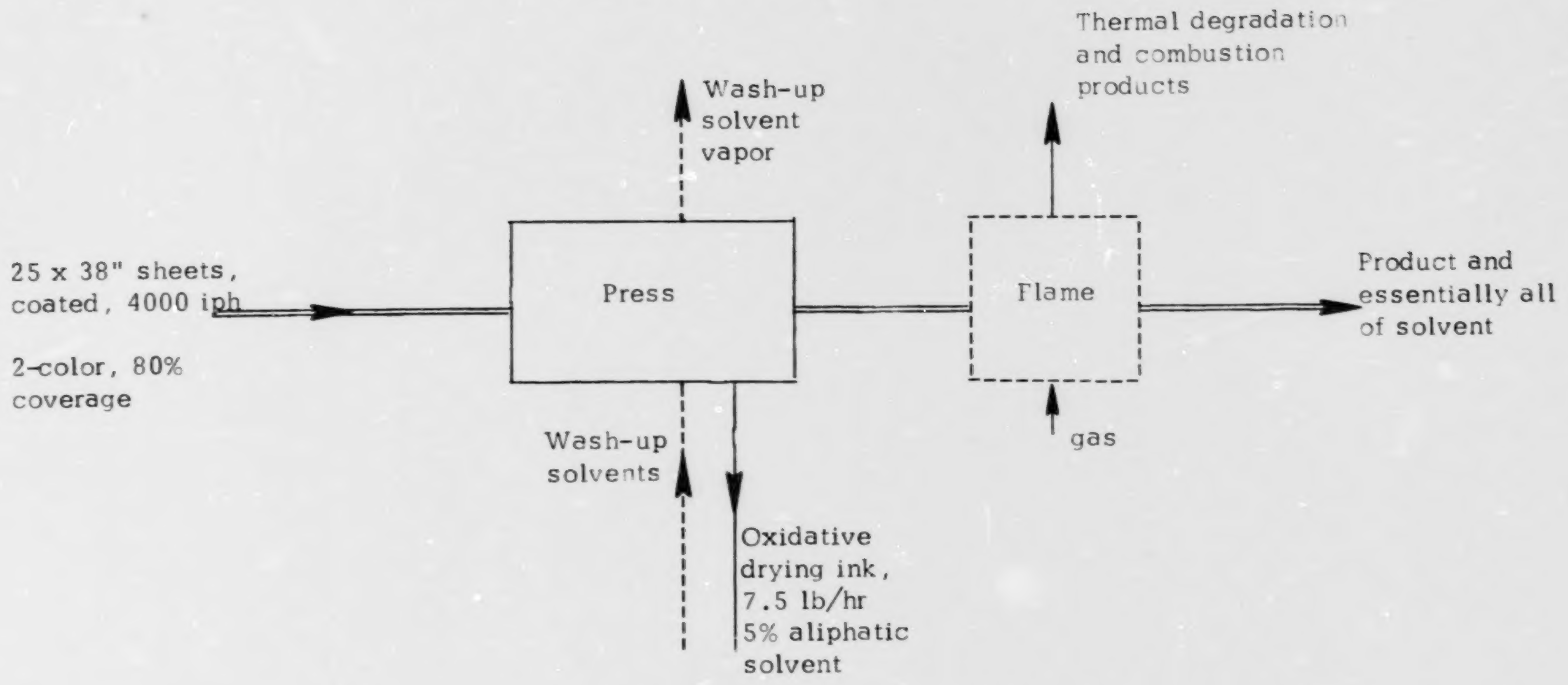

Wash-up solvent vapor
Thermal degradation and combustion products
25 x 38" sheets, coated, 4000 iph
2-color, 80% coverage
Press
Flame
Product and essentially all of solvent
Wash-up solvents
gas
Oxidative drying ink, 7.5 lb/hr 5% aliphatic solvent

Figure 14

Sheet-fed Letterpress

flames is included. The only source of emission besides the flame combustion products is the wash-up solvent. The size of the operation shown is comparable to the sheet-fed offset operation shown earlier. The increased ink usage is meant to reflect the fact that the letterpress ink film is 1-1/2 to 2 times as thick as the lithographic ink film. Although two-color presses are indicated, five-color printing is possible in sheet-fed lithography and letterpress.

All letterpress and lithographic ink mileages were calculated from the amount of ink used per thousand signatures of a 22 x 36 inch size, printed on two sides. The numbers are for low to high use in four-color process work and were provided by one of the ink manufacturers. In web printing, the 23 x 36 inch signatures would be printed on a web 38" wide and this width was used in the flow diagrams. If only one side is printed, the mileage is doubled, or the amount of ink used is cut in half. The numbers used are on Table 32.

TABLE 32

INK USE, POUNDS PER THOUSAND SIGNATURES

	Coated Paper	Uncoated Paper
Web Offset	2-3.2 lb	3-4.8 lb
Letterpress	3-4.5 lb	4-6 lb

6.3 Metal Decorating

Sheet-fed metal decorating which this study of metal coating is limited to, is done with lithographic inks containing mainly alkyd resins and very little solvent. The image is transferred by lithography to a dried lacquer undercoat, rather than to the base metal. If several colors are applied, the wet inks are usually not allowed to overlap each other (no wet trapping). A coating can then be put on top of the wet ink.

The sheet is coated twice if bottle caps are to be made. A thick coating of varnish is put on one side and dried, and a thin lacquer, usually vinyl, is put on the other side. The completely dried sheet is sent through the lithographic press, where several colors may be put on the thin vinyl coated side. After printing, a trailing roller coater puts a varnish coating over the wet ink, and the sheet is dried again.

Sheets going into the oven are picked up by preheated wickets and pass slowly through several oven zones where they are contacted by hot air. The retention time in these ovens may be 15 minutes including the cooling zone. Sheets leaving the oven are assumed to be essentially 100% dry even though independent investigation of vinyl coatings identify 7 to 10% solvent after 300°F baking (49).

The thickness and solvent content of coatings influence the percent solvent in the oven exhaust. Ovens are operated from about 10% to 25% of the lower explosive limit and in some cases up to 40% L.E.L. The temperature increase due to the combustion of the organic vapors is 250°F for 10% L.E.L. based on the assumptions in Table 33. Solvents containing oxygen, such as ketones, have a lower heat of combustion than hydrocarbons, and give less temperature rise per pound consumed. The solvent used in Table 33 is a mixture of aliphatic, aromatic and a ketone.

Since the ink contains little or no solvent, the emission from the lithographing process is insignificant. Therefore, the points of organic emission in metal decorating are the roller coating area and the oven exhaust. The amount of solvent emitted during coating is relatively insignificant; consequently it is not always exhausted from the area. Metal decorators in geographic locations where solvents may not be emitted can either reformulate or use hoods over the roller coater and conveyers. If hoods are used, and the hood exhaust is incinerated, the capacity of the afterburner must be increased 10 to 20%.

At the other end, the cooling zone exhaust air contains very little solvent, since the sheet is almost completely dry when it leaves the oven. This air is even used for room heating in some of the smaller plants. The main location of solvent emission is therefore the oven exhaust. Generally, there is one exhaust from the heating section even though this section may consist of several heating zones with recycle of a portion of the drying air between zones.

In metal decorating, the percent solvent content of the air in the drying oven becomes significant relative to the lower explosive limit. Also, the heat required to operate the fume incinerators is partly supplied by the solvent vapors. The assumptions used in making rough calculations of heat requirements and solvent content are stated in Table 33.

TABLE 33

MATERIAL AND HEAT BALANCE CALCULATIONS
for
METAL DECORATING SOLVENT FLOW CHARTS
(Figures 15, 16, 17 and 18)

Note: All calculations presented in this table are based upon process variables as indicated on appropriate solvent flow chart diagrams and serve as illustration only. No process generalization can be drawn as material and heat balance calculations must be performed for each process based upon its stated process variables.

1. Assumptions

A. Approximate density of coatings in grams/cc when dry:

Vinyl lacquer	1.2
Other lacquers and varnishes	1.0
Pigmented vinyl lacquer	1.7

B. Coverage in milligrams per four square inches (mg/4 sq in) can be expressed as coverage (c) = (65.55) (M) (D) where M is coating thickness in mils, (0.001 inch), and D is the density of the material in grams per cc. (Water is about 1 gm/cc.)

C. The density of a solvent mixture of 36/36/28, aliphatic/xylol/MIK (similar to MIBK) is about 0.83 gm/cc or 6.9 lb/gal. The weighted average heat of combustion of this solvent mixture is about 18,370 Btu per pound, or 125,000 Btu per gallon of solvent.

D. Density of air at 68°F is about 0.0753 lb per cubic foot. The constant pressure specific heat of air is about 0.256 Btu per pound.

E. The heating value of natural gas is usually 1000 Btu per cubic foot.

F. The lower explosive limit for hexane is 1.18% by volume, or (86/29) (1.18%) by weight, or 3.5%, where 29 is the "average" molecular weight of air. At 25% L.E.L. there will be 6.6 lb hexane per 10,000 standard cubic feet per minute (scfm) of air at 68°F.

Table 33 cont'd.

G. The initial amount of solvent per 4 sq in was determined by the following equation:

$$\text{Initial solvent} = \frac{\text{lb solvent}}{\text{lb solids}} \times \text{mg solid per 4 sq in}$$

2. Calculations (Material Balance)

A. Using the equation in assumption G, and the system in Figure 15, the total solvent coverage = 20 mg/4 sq in $\times \frac{7}{3}$ = 47 mg/4 sq in.

B. The emission rate is then calculated based on the following:
   1. Initial or total solvent coverage = 47 mg per 4 sq in.
   2. No. of 4" squares on a sheet
      28" x 35" = 980/4 = 245
   3. Rate = 90 sh/min
   4. 1 lb = 453,600 mg

$$\text{Emission rate lb/min} = \frac{(47 \text{ mg/4 sq in})\ (245)\ (90)}{453{,}600 \text{ mg/lb}} = 2.29$$

C. The rate of solvent release for Figure 15, the inside can coating is 2.29 lb/min, 137 lb/hr, or about 8.9% L.E.L. in the oven exhaust based on hexane.

D. Using the above calculation results for Figures 16,17 and 18 are as follows:

1. Figure 16, Outside Can Primer, the rate of solvent release based on vinyl sizing is 1.54 lb/min or about 5.8% L.E.L. in the oven exhaust based on hexane. In the case of white primer the rate of solvent release is 3.5 lb per minute or about 10.3% L.E.L. in the oven exhaust based on hexane.

2. Figure 17, Printing Line, the rate of solvent release from the varnish coater is 0.39 lb per minute or about 1.5% L.E.L.

3. Figure 18, the Inside Can Body Coater, the rate of solvent release is 0.52 lb/min at 2.6% L.E.L.

Table 33 cont'd.

3. Calculations (Heat Balance)

A. Using Figure 15, the heat necessary for this operation is as follows:

$(0.256)\ (10,700)\ (0.0753)\ (60)\ (825^{\circ}-70^{\circ}) = 9.3$ million Btu/hr

plus heat losses, if the heat exchanger is used. The heat supplied by the solvent for 97% drying is equal to:

$(0.97)\ (137)\ (18,370)$, or 2.44 million Btu/hr.

This is one-fourth of the necessary heat.

B. For comparison, the heat necessary in Figure 18, the body coater oven, is:

$(7500)\ (630^{\circ}-70^{\circ})\ (0.256)\ (0.0753)\ (60) = 4.85$ million Btu/hr

plus heat losses, if the heat exchanger is used. The heat supplied by the solvent 97% drying is equal to:

$(0.97)\ (31.2)\ (18,370)$ or 0.55 million Btu/hr

This is about one-eighth of the heat required, neglecting heat losses.

6.31 Inside Can Coating

Although bottle caps are mechanically formed after the complete coating is put on the sheets, cans are coated inside after being formed, and some are not coated at all on the inside. Thus, a sheet may be coated lightly or not at all on the non-printed side if it is to be made into cans.

Figure 15 shows the application of inside can lacquer to a sheet although it can also represent the application of inside coating for bottle caps or reverse side coating for products other than sanitary cans. When a sanitary can (the type by the Food and Drug Administration for food and beverages) is to be produced, soldered seams are employed and the area which will become the can seams is not coated. To accomplish this, a spot coater is used.

Figure 15 is the first stage in the most common three-stage metal decorating operation and also the first stage in the four-stage

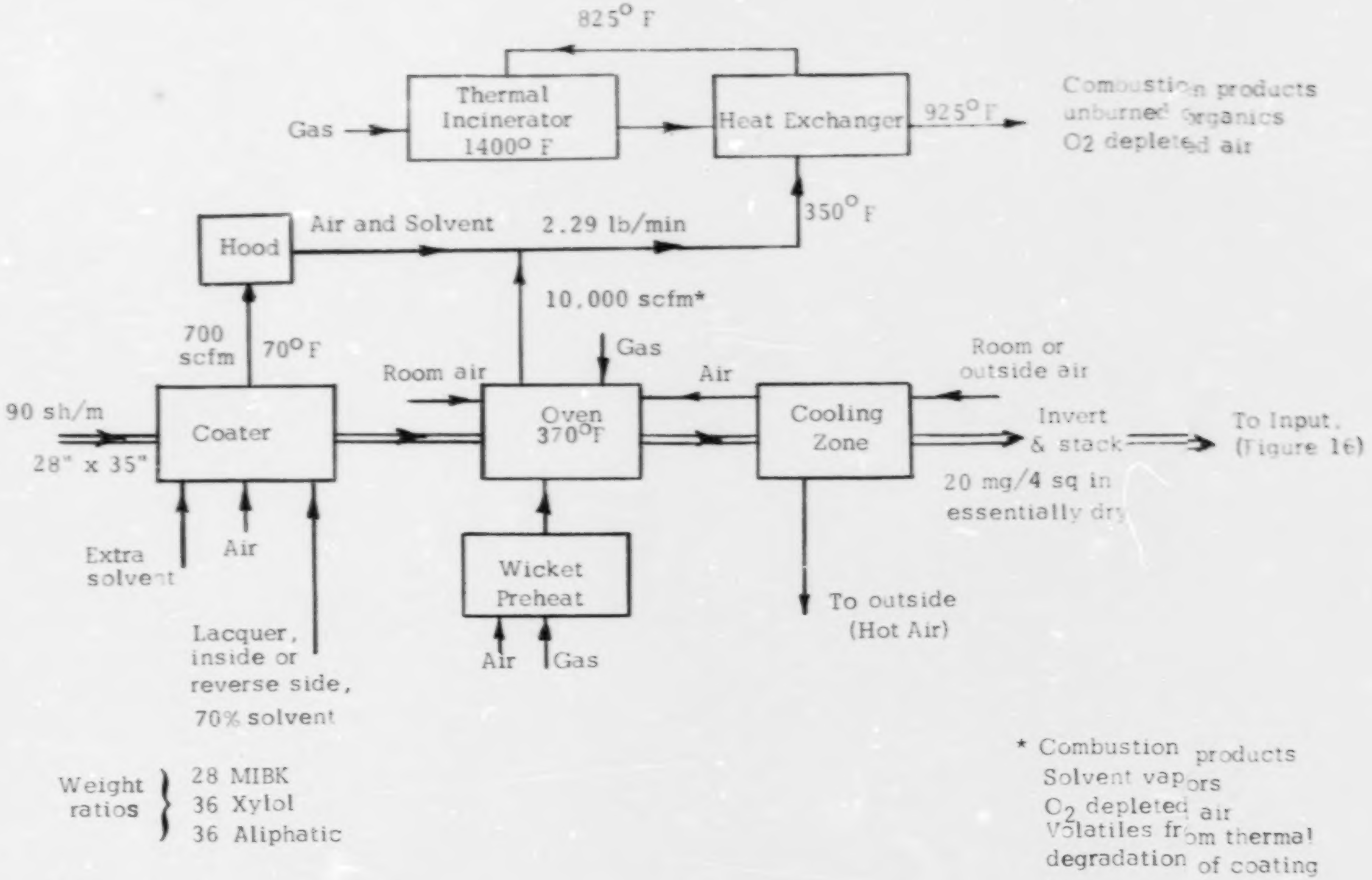

825° F
Gas
Thermal Incinerator 1400° F
Heat Exchanger
925° F
Combustion products
unburned organics
O2 depleted air
350° F
Hood
Air and Solvent
2.29 lb/min
10,000 scfm*
700 scfm
70° F
Gas
Room air
Air
Room or outside air
90 sh/m
28" x 35"
Coater
Oven 370°F
Cooling Zone
Invert & stack
To Input, (Figure 16)
20 mg/4 sq in essentially dry
Extra solvent
Air
Wicket Preheat
To outside (Hot Air)
Lacquer, inside or reverse side, 70% solvent
Air
Gas
Weight ratios
28 MIBK
36 Xylol
36 Aliphatic
* Combustion products
Solvent vapors
O2 depleted air
Volatiles from thermal degradation of coating

Figure 15

Inside Can Coating

beverage can coating operation. In this diagram, sheets sized 28" x 35" are fed at a rate of 90 per minute to the roller coater and then are transferred to preheated wickets which enter the oven. The sheets remain in the oven for 10 to 15 minutes, including the time in the cooling zone. The oven temperature is shown at 370°F. After leaving the oven the sheets may be inverted before they are stacked.

The major source of solvent and odor emission is the oven exhaust. A minor source is the coating operation. If there is no local ordinance similar to the Los Angeles Air Pollution Control District's Rule 66, or if exempt solvents are used, a hood will probably not be used at the coating operation. There is very little solvent or odor from the cooling zone exhaust or from the dried sheets coming out of the oven. The solvent content of the oven exhaust can be estimated as in Table 33 as 8.9% of the lower explosive limit (L.E.L.)

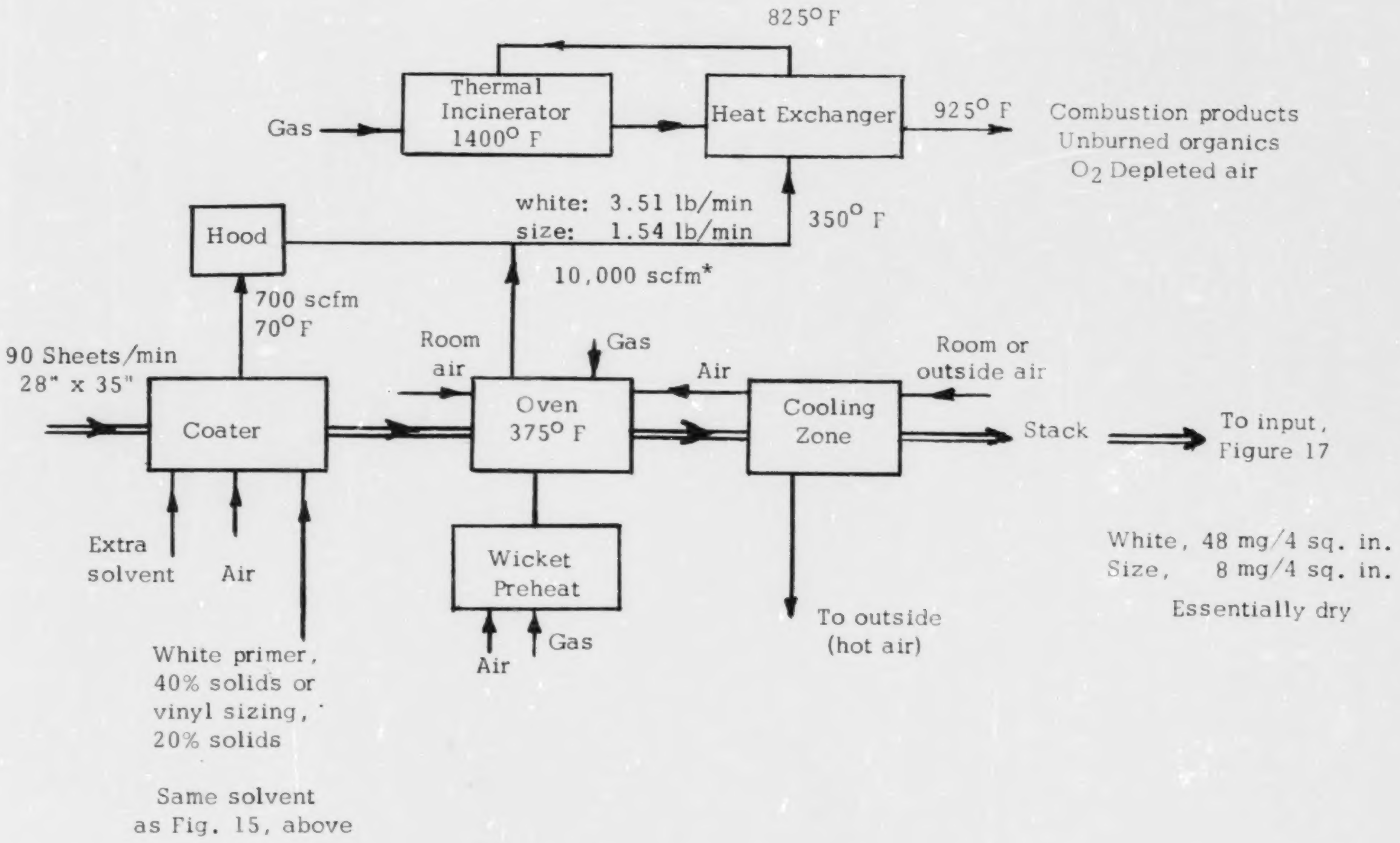
The inside or reverse side lacquer coating, used in this operation contains 30% solids by weight. The solvent used is a mixture of MIBK, xylol and an aliphatic mixture in a weight ratio of 28:36:36. This usually has enough solvent power, but special solvents can be added for vinyl coatings. The dried coating weight is 20 milligrams per four square inches of coated surface.

Extra solvent is added at the coater, especially in spot coating, where the coating roller does not pick up all the material from the feed roller. Thus, a scraper is used on the feed roller and a small amount of solvent is added to the roller surface before it contacts the scraper. Another scraper removes excess coating from the steel roller which holds the sheet against the coating roller (the impression roller), and solvent is added just ahead of this scraper also.

The oven exhaust and hood outlet, at 350°F, are shown entering an incinerator operating at 1400°F. The heat exchanger is being used to preheat the incinerator input to 825°F (about 45% of the difference between 1400 and 350°F). Another heat exchanger could be used to preheat part of the oven input air, if economics indicated that it was advisable. However, this is probably not common in the industry.

6.32 Outside Can Primer

Figure 16 is the second step in the most common metal decorating procedure. After the coated sheet is flipped over and stacked, it


825° F
Thermal Incinerator 1400° F
Gas
Heat Exchanger
925° F
Combustion products
Unburned organics
O_2 Depleted air
Hood
white: 3.51 lb/min
size: 1.54 lb/min
350° F
10,000 scfm*
700 scfm
70° F
90 Sheets/min
28" x 35"
Room air
Gas
Air
Room or outside air
Coater
Oven 375° F
Cooling Zone
Stack
To input, Figure 17
Extra solvent
Air
Wicket Preheat
Air
Gas
To outside (hot air)
White, 48 mg/4 sq. in.
Size, 8 mg/4 sq. in.
Essentially dry
White primer, 40% solids or vinyl sizing, 20% solids
Same solvent as Fig. 15, above

* Combustion products
Solvent vapor
O_2 depleted air
Volatiles from thermal
degradation of coating

Figure 16

Outside Can Primer

is coated on the other side with a thin primer or a thicker pigmented primer. This diagram is the same as Figure 15, except that the dried coating thickness is greater. In small metal decorating operations this could be done on the same coating line as that shown in Figure 15, by changing the coating used without changing operating conditions.

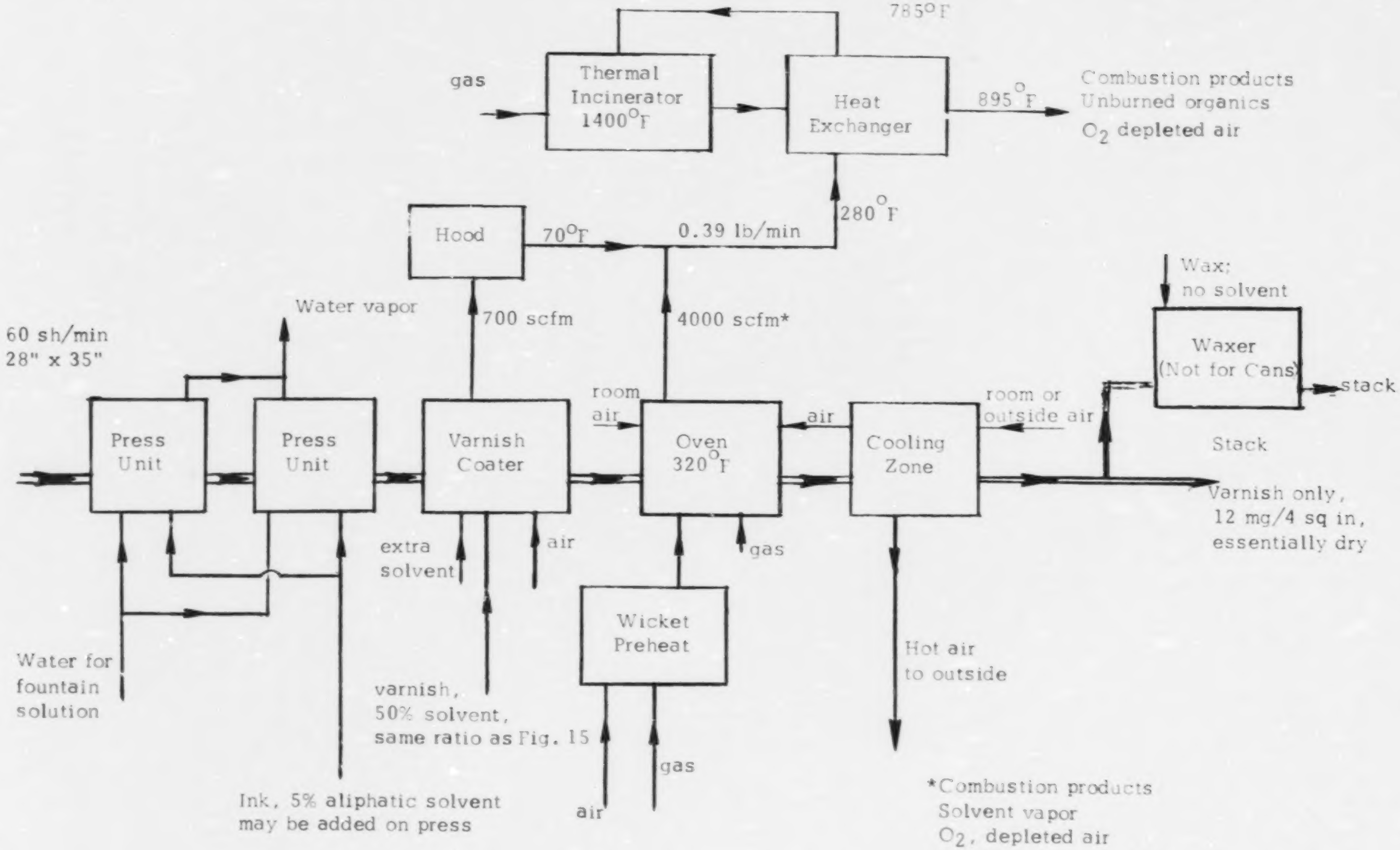
As above, the sheets pass through the coater and the oven. The sheets are stacked, but this time they are not turned over. The dried coating thicknesses are shown as 8 mg/4 sq in for the vinyl sizing and 48 mg/4 sq in for the white primer.

6.33 Printing Line in Metal Decorating

Figure 17 is the third step in the most common metal decorating procedure. The coated sheet is printed with lithographic ink. Usually there are either one or two offset printing units in series with a varnish coater, which is sometimes called a trailing or back-up coater. The varnish is put on over the wet ink. The sheet then passes through the oven, which is operated at a lower temperature than the coater ovens. Some printing lines operate at a lower speed than coating lines; consequently, the rate shown in Figure 17 is 60 sheets per minute.

The source of organic emission is again the heating zone exhaust of the oven, and the roller coater if a hood is used over this area. The thermal incinerator and heat exchanger are used, but the input to the heat exchanger is at a slightly lower temperature than in Figures 15 and 16. Water vapor is emitted from the dampener on the printing units, but the inks do not emit significant amounts of solvent. In this process, isopropanol is not used in the lithographic fountain solutions, consequently no alcohol vapor is shown being emitted in any metal decorating flow sheet.

An additional process which is applicable only to sheets which are not going to be made into cans is the waxer. A protective wax coating can be applied to the sheet by melting and spraying on, or by other means. Mixtures of waxes or waxy synthetic resins can be used. Viscosity is controlled mainly by composition and temperature, so no solvent is necessary. Heat input to the waxing machine is intentionally not shown since the source of heat presumably does not come into direct contact with the wax. This process is also used for coating cardboard, as in the production of milk cartons. There is no further information about organic emissions from wax coating processes.


785°F
gas
Thermal Incinerator 1400°F
Heat Exchanger
895°F
Combustion products
Unburned organics
O2 depleted air
280°F
Hood
70°F
0.39 lb/min
700 scfm
4000 scfm*
Water vapor
60 sh/min
28" x 35"
Press Unit
Press Unit
Varnish Coater
room air
Oven 320°F
air
Cooling Zone
room or outside air
Wax; no solvent
Waxer (Not for Cans)
stack
Stack
Varnish only, 12 mg/4 sq in, essentially dry
extra solvent
air
gas
Wicket Preheat
Water for fountain solution
varnish, 50% solvent, same ratio as Fig. 15
Hot air to outside
gas
air
Ink, 5% aliphatic solvent may be added on press

*Combustion products
Solvent vapor
O_2, depleted air
Volatiles from thermal
degradation of coating

Figure 17

Printing Line in Metal Decorating

6.34 Inside Can Spray

Figure 18 describes an oven used to dry the inside of can bodies. Beverage cans need a double coating inside to protect against the effects of carbonation. This double coating protects not only by added thickness, but also by eliminating the possibility of pinholes in the coating. Therefore, after the can is formed and a stripe of protective coating is painted over the seam, the cans are sprayed inside with the second coating.

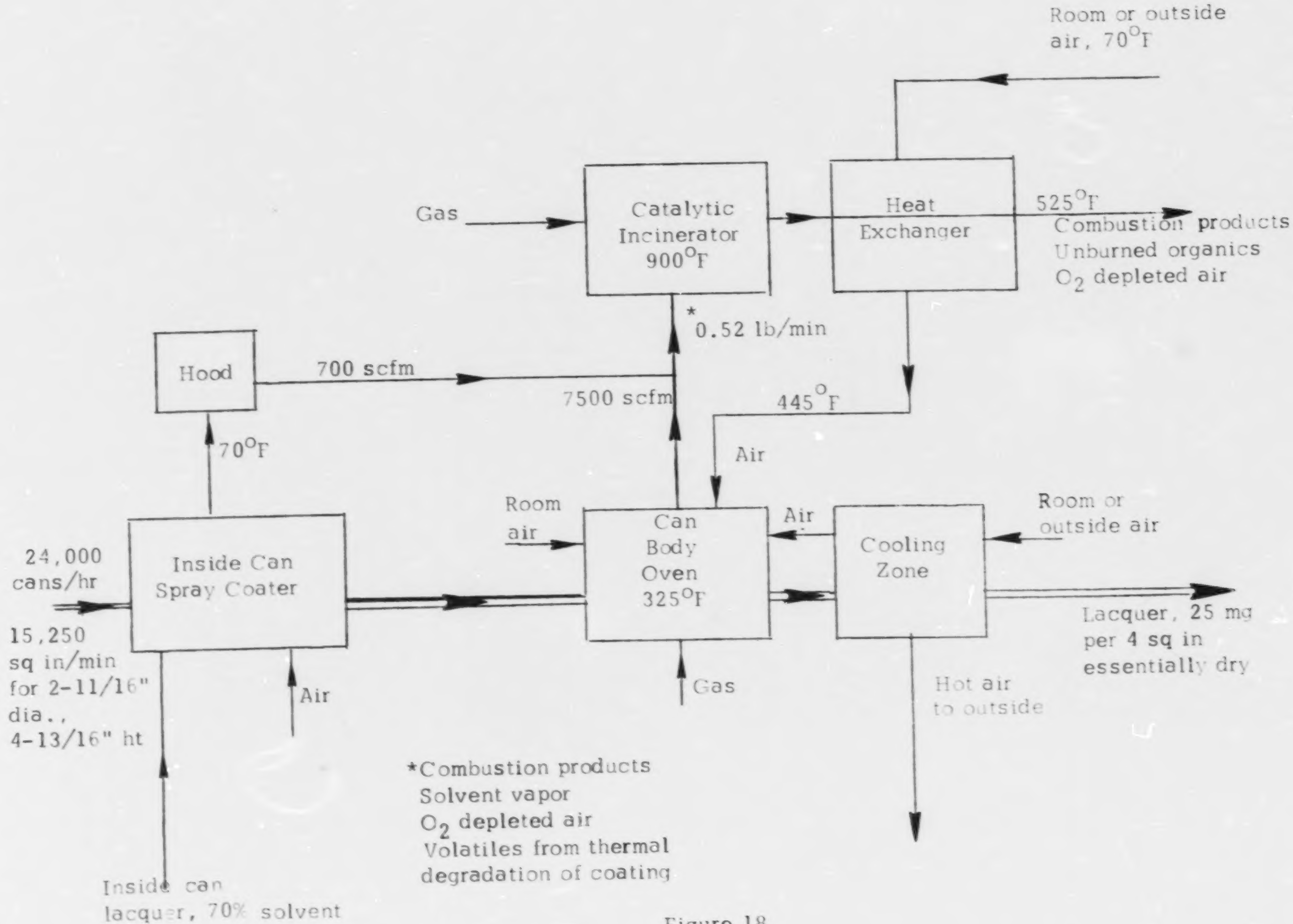
After being spray coated, the cans are fed in an upright position to a steel band which travels through the can body oven. The rate of drying in square feet per minute in the oven depicted is about one third of the rate at which sheets can be printed on one printing line.

This diagram suggests the possibility that a catalytic unit can be used in this (or any) metal decorating process for removal of solvent fumes. The heat exchanger is used to preheat the oven input air in this diagram, but it could be used to preheat the input to the incinerator instead.

The thickness of the second coating is given as 25 mg/4 sq in, essentially dry. The organic vapors are emitted at only one point, the output of the incinerator. There is very little emission from the oven cooling zone, or from the product. Finally, the heat exchanger is not necessary in the diagram, and would be used only if economics so indicated.

6.35 Label Varnishing

One interesting variation from the usual metal decorating procedure occurs when a rather thick film of varnish is to be applied to printed paper or cardboard. The varnish used and the coating equipment are similar to what is found in the metal decorating industry. For this reason, a diagram of a sheet-fed cardboard coating operation is included with the metal decorating flow diagrams. Figure 19 is a description of a card or label varnishing operation. Some varnish is actually a lithographic ink vehicle, and can be applied in a very thin film completely covering the paper, using the lithographic process. However, there are cases which require a thicker film of varnish, so a solvent release drying varnish is used. This process is sheet-fed and uses a roller coater.


Room or outside air, 70°F
Gas
Catalytic Incinerator 900°F
Heat Exchanger
525°F
Combustion products
Unburned organics
O2 depleted air
*0.52 lb/min
Hood
700 scfm
7500 scfm
445°F
Air
70°F
Room air
Air
Can Body Oven 325°F
Cooling Zone
Room or outside air
24,000 cans/hr
Inside Can Spray Coater
15,250 sq in/min for 2-11/16" dia., 4-13/16" ht
Air
Gas
Hot air to outside
Lacquer, 25 mg per 4 sq in essentially dry
Inside can lacquer, 70% solvent

*Combustion products
Solvent vapor
O_2 depleted air
Volatiles from thermal
degradation of coating

Figure 18

Inside Can Spray

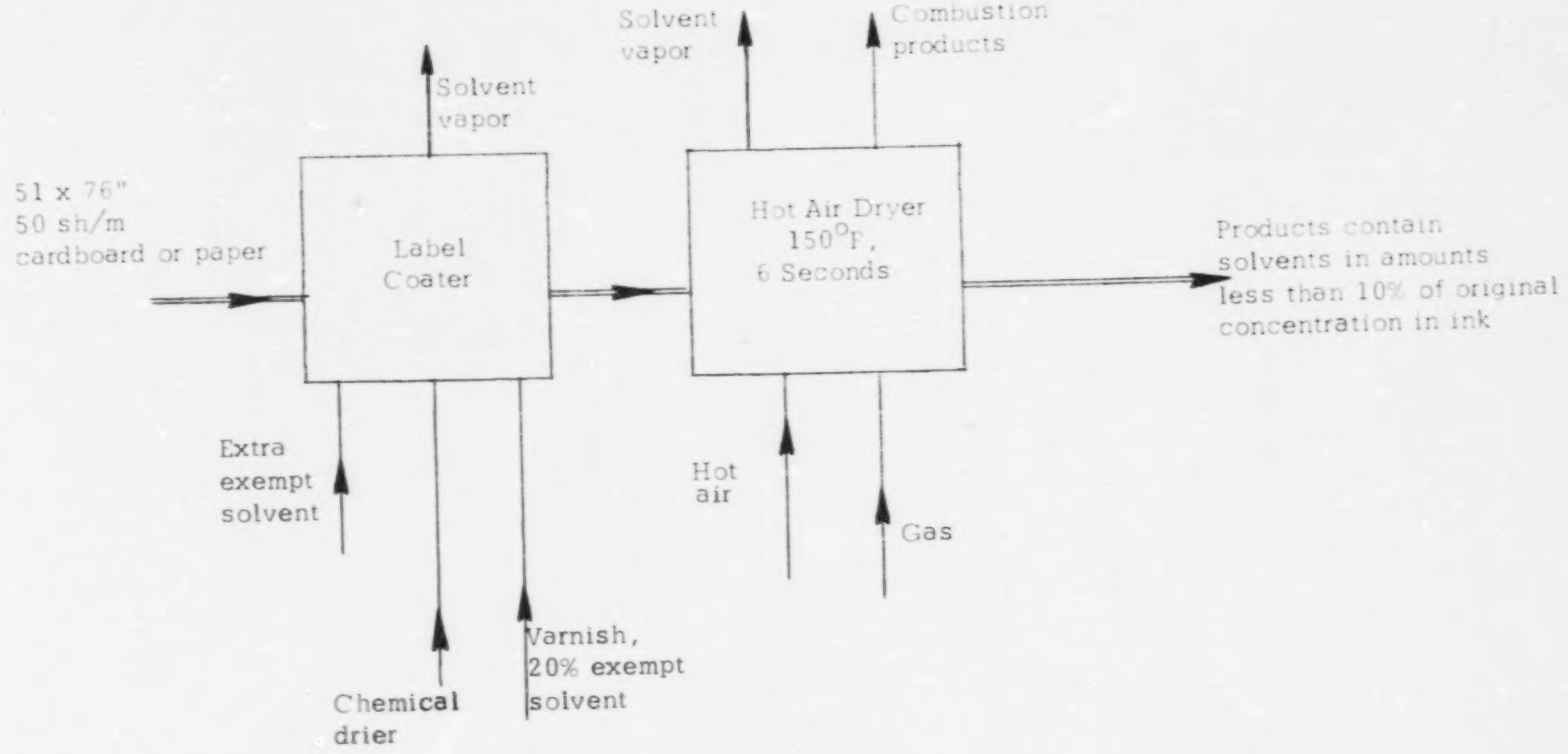

51 x 76"
50 sh/m
cardboard or paper
Solvent vapor
Label Coater
Extra exempt solvent
Chemical drier
Varnish, 20% exempt solvent
Solvent vapor
Combustion products
Hot Air Dryer 150^{O}F, 6 Seconds
Hot air
Gas
Products contain solvents in amounts less than 10% of original concentration in ink

Figure 19

Label Varnishing

In this process, 51" x 76" sheets are coated with varnish containing 20% solvent and a small amount of chemical drier. After coating, the sheets are mechanically grasped by the edges and conveyed through a 30-foot long tunnel dryer in about six seconds. The dryer is operated at 150°F with indirectly heated air. Thus, air pollution control equipment would not be needed to comply with "Rule 66 type" ordinances if "exempt" solvents are used. The solvent content of dust-dry coatings is known to be less than 10%, and usually less than 5%, but this plant had no test data on the amount of solvent retained in their own product.

6.36 Outside Coating of Collapsible Tubes

Another variation is the printing of the outside of cans and metal tubes. In this case, the image is transferred by the dry offset process.

Figure 20 represents the operation whereby collapsible lead tubes are printed and coated. Because of the small size of the product, this operation is accomplished with a rather compact piece of machinery. Each tube is automatically positioned on a mandrel and can then be printed with four colors or with three colors and a protective varnish. No exact information was available on the solvent content of inks or on the drying equipment; however, the solvent content has to be low, i.e., 5 percent or less. The printing is done by dry offset because type and printed solids are involved in the designs. This is essentially a letterpress plate printing onto a rubber blanket, which transfers the image to the tube. No information on operating rates was obtained.

6.37 Aluminum Can Coating

Figure 21 is a description of a coating process which is used mainly for stamped or extruded one-piece aluminum can bodies. These cans are coated on the inside and printed outside after they are formed. This is a relatively new process, and not much information about it was obtained in the course of the field visits.

The flow diagram shows a continuous process of printing and coating using two different ovens. However, after the first drying operation there could be a delay before inside coating, or cans might even be coated at another facility.

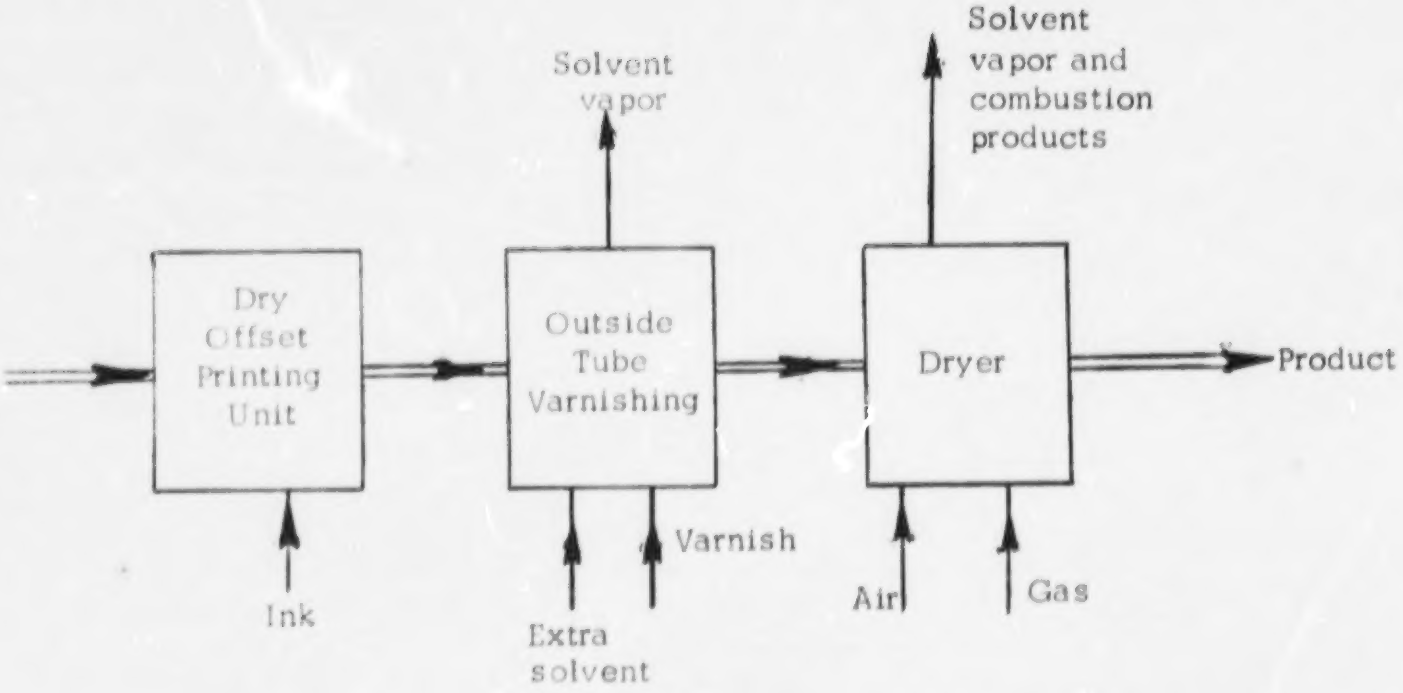
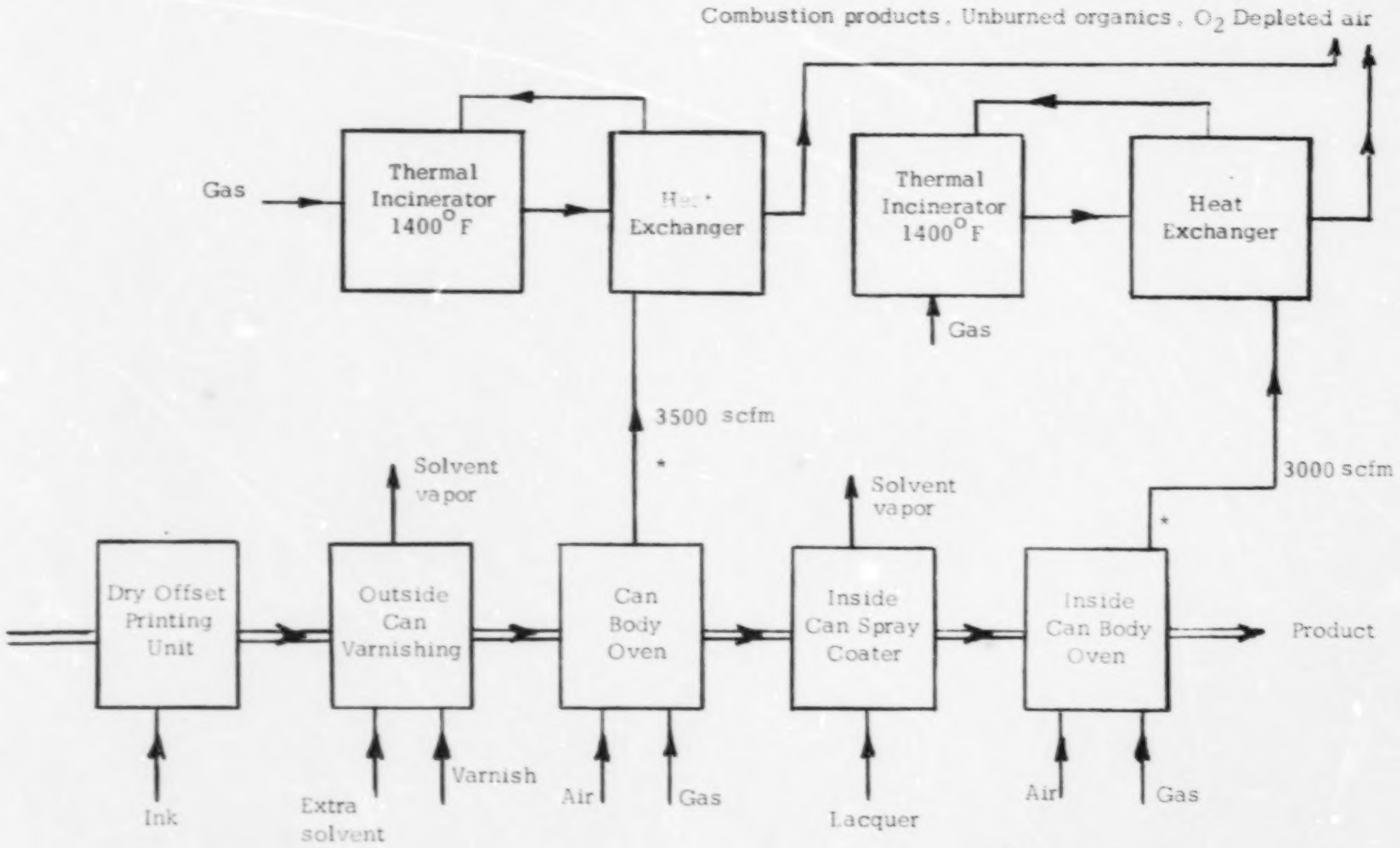

Solvent vapor
Solvent vapor and combustion products
Dry Offset Printing Unit
Outside Tube Varnishing
Dryer
Product
Ink
Extra solvent
Varnish
Air
Gas

Figure 20

Outside Coating of Collapsible Tubes


Combustion products, Unburned organics, O_2 Depleted air
Gas
Thermal Incinerator 1400°F
Heat Exchanger
Thermal Incinerator 1400°F
Gas
Heat Exchanger
3500 scfm
*
3000 scfm
*
Solvent vapor
Solvent vapor
Dry Offset Printing Unit
Outside Can Varnishing
Can Body Oven
Inside Can Spray Coater
Inside Can Body Oven
Product
Ink
Extra solvent
Varnish
Air
Gas
Lacquer
Air
Gas

*Combustion products
Solvent vapor
O_2 depleted air
Volatiles from thermal
degradation of coating

Figure 21

Aluminum Can Coating

In this diagram the formed cans are printed on the outside by dry offset and then are varnished. The cans then pass through a body oven. After this the cans are sprayed with an inside coating and go through another body oven. In each case, a thermal incinerator with a heat exchanger is used on the exhaust of each oven.

6.4 Gravure or Intaglio Printing

In this type of printing the image area is recessed relative to the surface of the image carrier. Ink is picked up in the engraved area and excess ink is scraped off the non-image area with a doctor blade. Ink is transferred directly from the image carrier to the paper or film. The ink used in high speed gravure printing contains a relatively large amount of low-boiling solvent and has a low viscosity. Control of solvent vapors around the ink fountain is very desirable to avoid the danger of explosion.

Gravure may be sheet-fed or roll-fed. Sheet-fed gravure uses either a flat plate for an image carrier, or a curved plate which is attached to a cylinder. In roll-fed gravure, or rotogravure, the image is engraved in the cylinder itself. Rotogravure may be used for coated or uncoated paper, film, foil and many combinations thereof.

6.41 Rotogravure

Figure 22 illustrates one unit of a publication gravure press used for printing magazines, catalogues or Sunday newspaper supplements. Webs may be much wider than the 63 inches indicated, and there is at least one press which takes a 102-inch web. The same diagram can be applied to package printing by gravure, except that the drying method would probably be hot air at 90 to 150°F because of the thickness of the paper board used. Publication printing can use either steam drum drying at 150°F or hot air drying, with the same exhaust air flow rate. The web width in package printing would be as much as 44 inches.

In this diagram, the web is printed with one color on one side and then enters the dryer. The web then passes over chill rolls. Only one unit is shown because with the thinner gravure and flexographic inks, between-color drying must be employed. Most operations will print 4 or 5 colors on both sides of the web. In package printing this may be done by double ending, or printing on a web that is half the maximum width, turning the web over and running it through the press again.

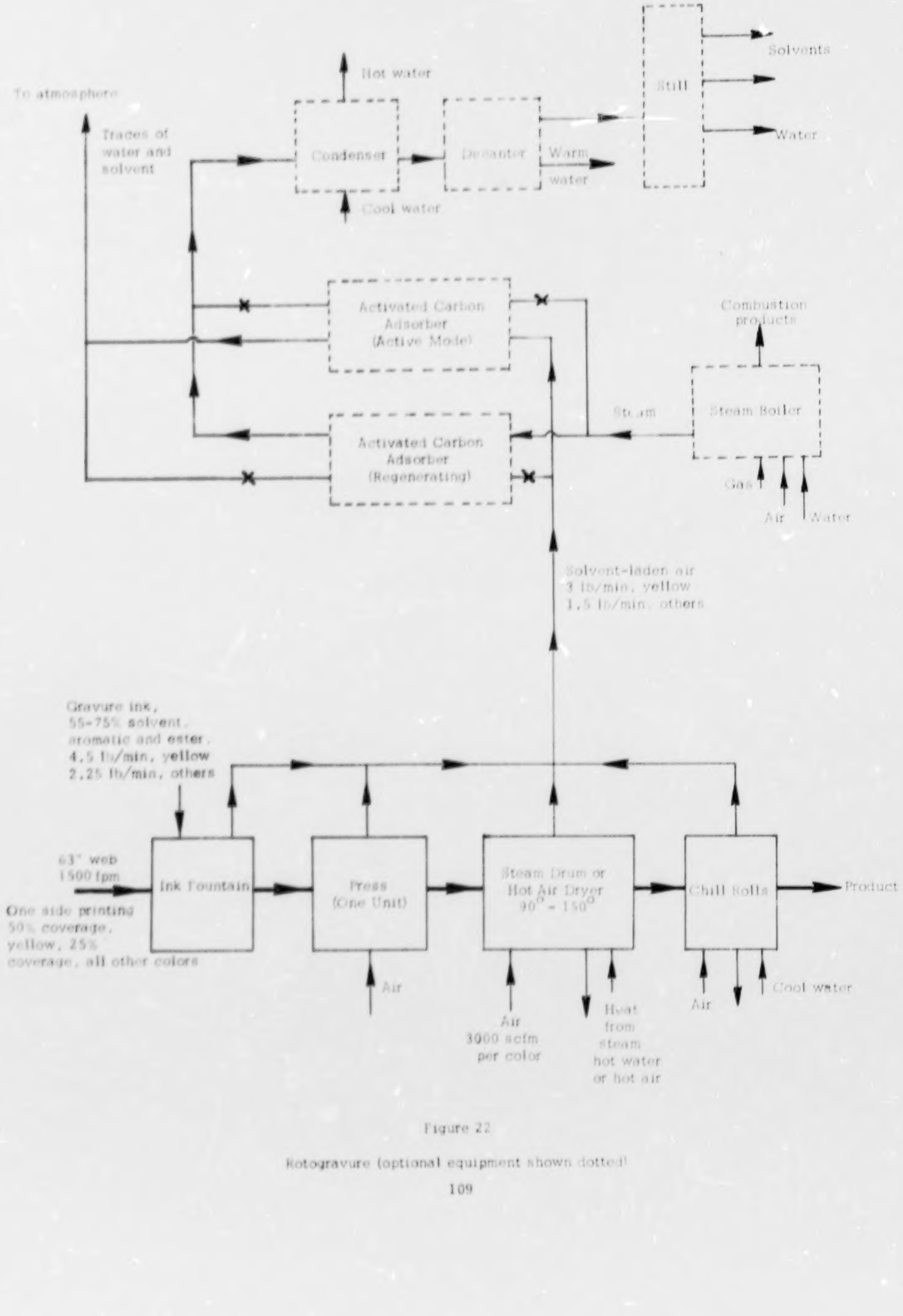

To atmosphere
Traces of water and solvent
Hot water
Condenser
Cool water
Decanter
Warm water
Still
Solvents
Water
Activated Carbon Adsorber (Active Mode)
Activated Carbon Adsorber (Regenerating)
Combustion products
Steam
Steam Boiler
Gas
Air
Water
Solvent-laden air
3 lb/min. yellow
1.5 lb/min. others
Gravure ink,
55-75% solvent,
aromatic and ester.
4.5 lb/min, yellow
2.25 lb/min, others
63" web
1500 fpm
One side printing
50% coverage,
yellow, 25%
coverage, all other colors
Ink Fountain
Press (One Unit)
Air
Steam Drum or Hot Air Dryer 90° - 150°
Air
3000 scfm
per color
Heat from steam hot water or hot air
Chill Rolls
Air
Cool water
Product

Figure 22

Rotogravure (optional equipment shown dotted)

Solvent vapor control is used at the press and at the dryer and chill rolls. Often the entire process is enclosed in one collection shell, which may effect a saving of air exhaust rate. Solvent vapors in some large installations are adsorbed on activated carbon. This is possible because there are no combustion products or solvent breakdown products in the exhaust. Heat is transferred indirectly to the air with steam radiators or with heat exchangers, or directly to the web using steam drums. Solvents do not break down because of the much lower temperatures used relative to heatset ink dryers.

The older adsorption process shown uses a series of fixed beds which must be alternately steam stripped and switched into the exhaust stream. The newer system uses a moving circular bed with continuous stripping at one location and adsorption at another. Few adsorption systems are in use, and are usually restricted to processes with a constant ink solvent composition. This facilitates recovery of a usable solvent for ink dilution at the press.

Rotogravure dryers can be operated at solvent concentrations that are 25 to 40% of the lower explosive limit, especially if solvent recovery or incineration is used. However, problems with control of solvent vapors are more likely to develop at high solvent loading. The concentration of solvent in the exhaust from the carbon beds is not stated because no reliable data were obtained in the survey.

The amount of ink used and solvent concentration is greater in rotogravure and flexography than in letterpress and lithography. Table 34 gives the calculation of percent of L.E.L. for gravure and flexo.

TABLE 34

MATERIAL BALANCE CALCULATIONS
for
ROTOGRAVURE AND FLEXOGRAPHY SOLVENT FLOW CHARTS
(Figures 22 and 24)

Note: All calculations presented in this table are based upon process variables as indicated on appropriate solvent flow chart diagrams and serve as illustration only. No process generalization can be drawn as a separate material balance calculation must be performed for each process based upon its stated process variables.

1. Assumptions

A. Gravure and organic solvent flexo inks weigh 8 pounds per gallon after dilution (16 lb per 2 gal). Solvent weight is 6.9 lb per gal.

B. Equal volumes of solvent are added to undiluted ink. Thus, the undiluted ink weighs (16-6.9), or 9.1 lb/gal. The solvent content of the diluted ink is: (100%) (0.4 x 9.1 + 6.9)/16 or 66%. (40% solvent assumed in original, undiluted ink).

C. Ink mileage for moderate coverage (coated paper) is assumed to be 1,000,000 sq in per gal for gravure ink and 750,000 sq in per gal for flexo ink (one side). Coverage is increased 20% for foil or plastic film and decreased 30% for porous paper.

D. In calculation, yellow coverage is assumed to be 50% and red, blue and black coverage is 25% of the total area.

E. The lower explosive limit for hexane is 1.18% by volume, or (86/29) 1.18%, or 3.5% by weight, where 29 is the "average" molecular weight of air.

F. Air weighs 0.0753 lb per cu ft at 68°F and one atmosphere pressure.

Table 34 cont'd.

2. Calculation (Rotogravure, Figure 22)

   A. Assuming complete drying, with a 63-inch web, 1500 ft per minute, 50% coverage, coated paper and 66% solvent, the solvent released is equal to the following:

   $$\text{Emission rate (lb/min)} = \frac{(0.5)\,(63)\,(1500)\,(12)\,(8)\,(0.66)\,(1)}{1{,}000{,}000}$$

   $$= 3 \text{ lb per minute (for yellow)}$$

   Since the coverage for all other colors is 25%, then one half of the above rate or 1.5 lb per minute applies to all other colors.

   B. The fraction of the lower explosive limit (L.E.L) in the exhaust at 3,000 scfm can then be calculated as follows:

   $$\%\ \text{L.E.L} = \frac{(3)\,(100)}{(3{,}000)\,(0.0753)\,(3.5)} = 38$$

   or 38% L.E.L. for yellow and 19% of L.E.L. for all other colors.

3. Calculation (Flexography, Figure 24)

   A. For flexography, with a 35-inch web, 600 ft per minute, 50% coverage, coated paper, 66% solvent content, 750,000 sq in per gal coverage and complete drying, the solvent released is equal to the following:

   $$\text{Emission rate (lb/min)} = \frac{(0.5)\,(35)\,(600)\,(12)\,(8)\,(0.66)\,(1)}{750{,}000}$$

   $$= 0.89 \text{ lb per minute (for yellow)}$$

   Since the coverage for all other colors is 25% then one half of the above rate, or 0.44 lb per minute, applies to all other colors.

   B. The fraction of the lower explosive limit (L.E.L) in the exhaust at 800 cfm can then be calculated as follows:

   $$\%\ \text{L.E.L.} = \frac{(0.888)\,(100)}{(800)\,(0.0753)\,(3.5)} = 42$$

   or 42% L.E.L. for yellow and 21% of L.E.L. for all other colors.

6.42 Sheet-fed Gravure

Figure 23 represents a sheet-fed gravure process. Although an older gravure platemaking process called photogravure always uses flat plates, cylinder presses are used for most sheet-fed work. The image is etched in a thin plate which can be curved around the plate cylinder. A large size sheet would be 29 x 43 inches. The press may run at 4500 impressions per hour. Sheet-fed gravure presses are often used for proofing rather than for regular production runs.

Sheet-fed presses use thicker inks and may use higher boiling solvents than roll-fed gravure presses. Thus, this process would not have any solvent fume control equipment associated with it. Drying of the ink could be by hot air as sheets are carried through a tunnel on a conveyer. At least 90% of the original solvent should be driven out of the ink, but the final division of the solvent between that retained in the paper and that exhausted is not known.

Intaglio also includes printing from various engravings, some of the best known being copper and steel plates. High quality sheet-fed gravure combined with embossing, using flat plates is called steel die engraving. These processes, as well as banknote printing on sheet-fed cylinder presses, use inks which are very viscous and short and have no relationship to commercial gravure inks. A flow chart is not included in engraving printing processes since there are no significant emissions.

6.5 Flexography

The flexographic process is similar to letterpress in that the image area is raised above the surface of the plate. Ink is transferred directly to the image area of the plate and directly from the plate to the paper or substrate. Whenever the plate is made of rubber and alcohol based inks are used, the process is considered to be flexography. The process is always web fed and is used for medium or long runs on a variety of substrates, including heavy paper and fiberboard and metal and plastic foil, as in gravure.

Flexographic processes differ among themselves mainly in the type of ink used. Most flexographic inks are fluid in consistency and contain about 55 or more percent organic solvent. The solvent may be alcohol or alcohol mixed with an aliphatic hydrocarbon or ester.

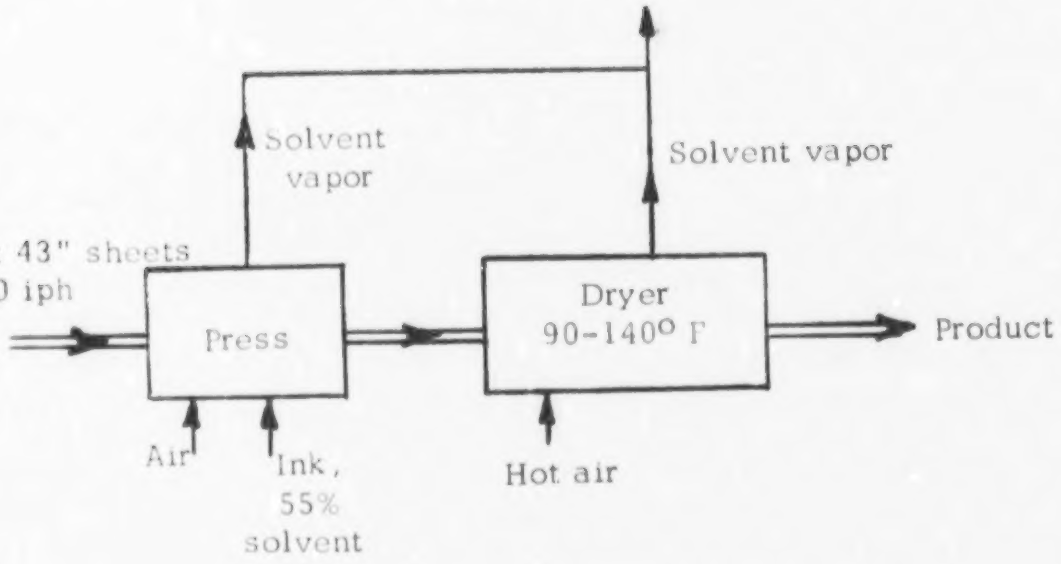

Solvent vapor
Solvent vapor
29 x 43" sheets
4500 iph
Press
Dryer
90-140° F
Product
Air
Ink,
55%
solvent
Hot air

Figure 23

Sheetfed Gravure

Several other types of rubber plate printing exist, but they contribute little to the organic effluent problem. Water-based inks contain pigment dispersions in solutions of water-soluble or water-dispersible resins. The solvent used is water plus a variable amount of alcohol or glycol type solvents. Steam set inks are based on solutions of resins in a glycol. Inks which are used to print pocket books are similar to letterpress inks containing 30 to 40% high boiling aliphatic solvents. These inks dry partly by absorption into the paper and little of the solvent is evaporated.

6.51 Flexography - Solvent Inks

Figure 24 is for the use of alcohol or alcohol-aliphatic based inks. The product may be steam drum or hot air dried at a temperature of about 140°F, and then passed over chill rolls. It is assumed that more solvent is driven out in the dryer than at the inking area, but the ratio is not known. About 90% of the solvent present is believed to be driven out during and after printing. After the web is cool, evaporation of the remaining 10% of the original solvent would be very slow from the solidified vehicle resins. The original solvent content is about 55% or more.

Some presses can be used for either solvent type flexography or gravure, by changing inking and plate equipment. An adsorption system similar to that used in rotogravure is shown in this diagram, although no known installation now exists for flexography. However, because of the similarity of certain aspects of flexography and rotogravure, adsorption is the control method most likely to be used if control becomes necessary.

6.52 Flexography - Steam Set Inks

Figure 25 refers to the "water flexo" or "steam set flexo" process. This process uses very low volatility inks of a paste consistency, which are gelled by water or steam. The vehicles usually consist of a glycol type solvent nearly saturated by a resin system. The presence of water lessens the solvent power of the glycol, causing the resin to precipitate and gel the vehicle. Further gelling occurs as the solvent slowly penetrates the paper or other substrate. No emission points are shown on this diagram. This process is used extensively for bag printing, and if the heavy paper is damp, gelation occurs without further addition of water. Otherwise, water or steam may be sprayed on the printed surface.

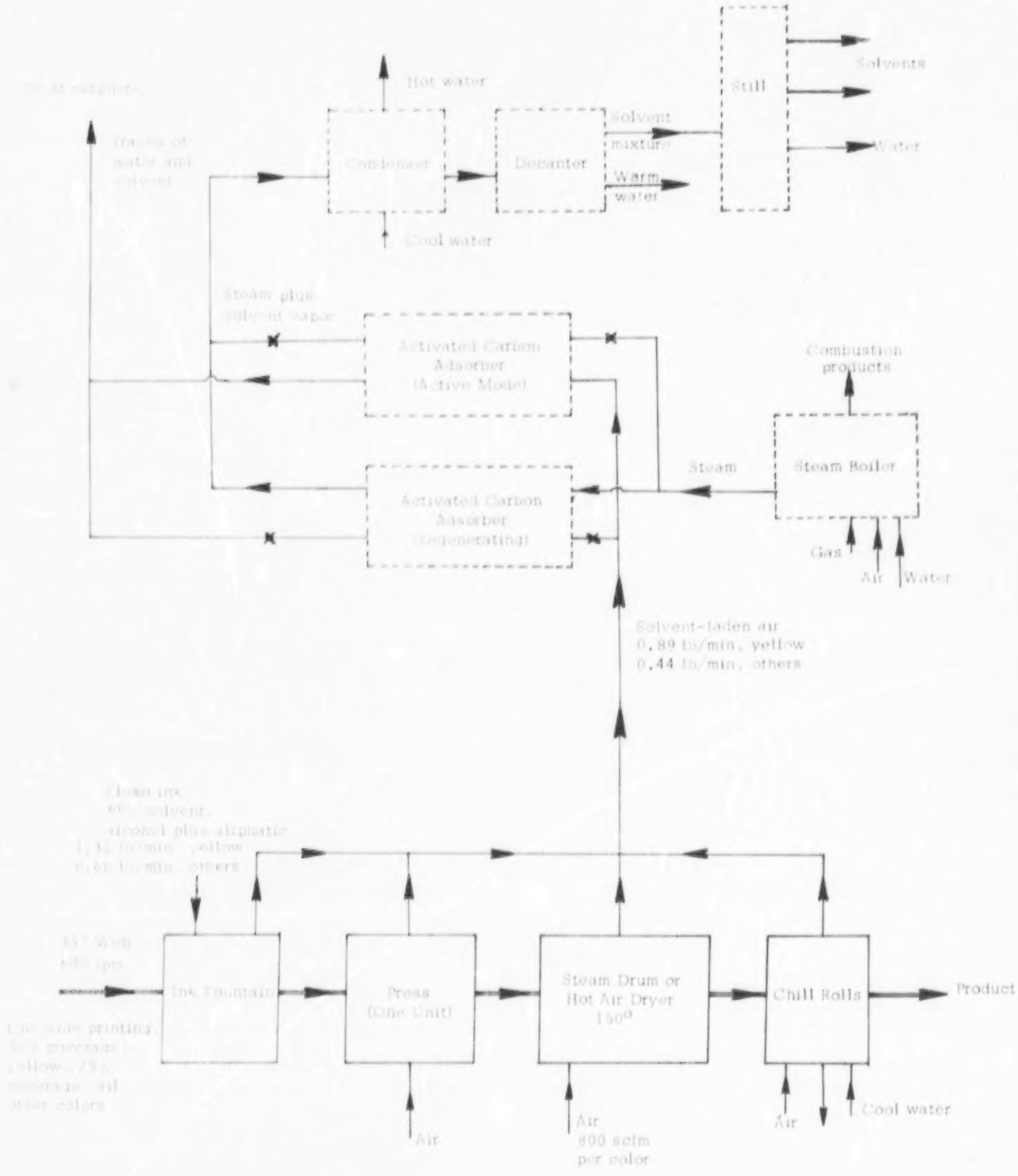

To atmosphere
Traces of water and solvent
Hot water
Condenser
Cool water
Decanter
Solvent mixture
Warm water
Still
Solvents
Water
Steam plus solvent vapor
Activated Carbon Adsorber (Active Mode)
Activated Carbon Adsorber (Regenerating)
Combustion products
Steam Boiler
Steam
Gas
Air
Water
Solvent-laden air
0.89 lb/min, yellow
0.44 lb/min, others
Flexo ink
60% solvent,
alcohol plus aliphatic
1.32 lb/min, yellow
0.66 lb/min, others
35" Web
400 fpm
One side printing, 50% coverage yellow, 25% coverage all other colors
Ink Fountain
Press (One Unit)
Steam Drum or Hot Air Dryer 150°
Chill Rolls
Product
Air
Air
800 scfm per color
Air
Cool water

Figure 24

Flexography - Solvent Inks (optional equipment shown dotted)

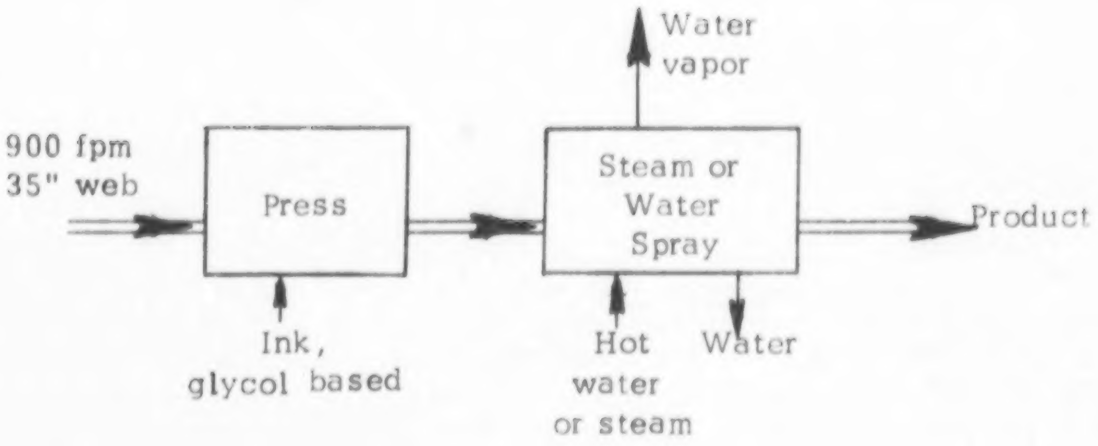

Water vapor
900 fpm
35" web
Press
Steam or Water Spray
Product
Ink, glycol based
Hot water or steam
Water

Figure 25

Flexography, Steam Set Inks

6.53 Flexography - Water Based Inks

Another flexographic process which produces very little pollution, Figure 26, uses water based inks. Flexographic inks originally were based on aniline dyes, but are now usually pigmented suspensions in water. A dryer may be used with this ink system, but since the ink solvent is water, no pollution source is shown on the diagram.

6.54 Rubber Plate Letterpress

Figure 27 refers to the pocketbook publication process using web rubber plate letterpress. The inks used in this process are similar to web letterpress inks and contain 30-40% aliphatic solvent. Since most of the drying is by absorption into the paper, drying is not complete and effluent control is not used. The product is partially set by steam drum at 160°F, producing some evaporation but no smoke. After chilling, most of the original solvent probably remains in the paper. Evaporation is slow because the boiling range of the solvent is 450-500°F. Printing stock is of course mostly porous paper, and black ink is used. The low degree of coverage of type images (as opposed to multicolor work) is another reason for the low rate of solvent emission.

In the process shown, a 59" web passes through two press units at 1000 ft per minute. It then passes over steam drums and chill rolls. Besides the small amount of solvent evaporated, some ink mist can be seen around the presses when they are operating. This is an insignificant amount of organic material.

6.6 Screen Printing

This process is not as important commercially as the other kinds of printing mentioned, the dollar value of inks shipped being about 2.4% of the total for the industry. The image area in screen printing is a fine screen through which ink or paint can be forced using a squeegee. Non-image areas are produced by coating or impregnating the screen with a material such as wax to mask off the ink. The process is entirely sheet-fed, and may be hand or machine operated. Printed material such as posters may be air dried or may be dried in a tower dryer. In this type of dryer, sheets are held in racks and pass through the oven vertically.

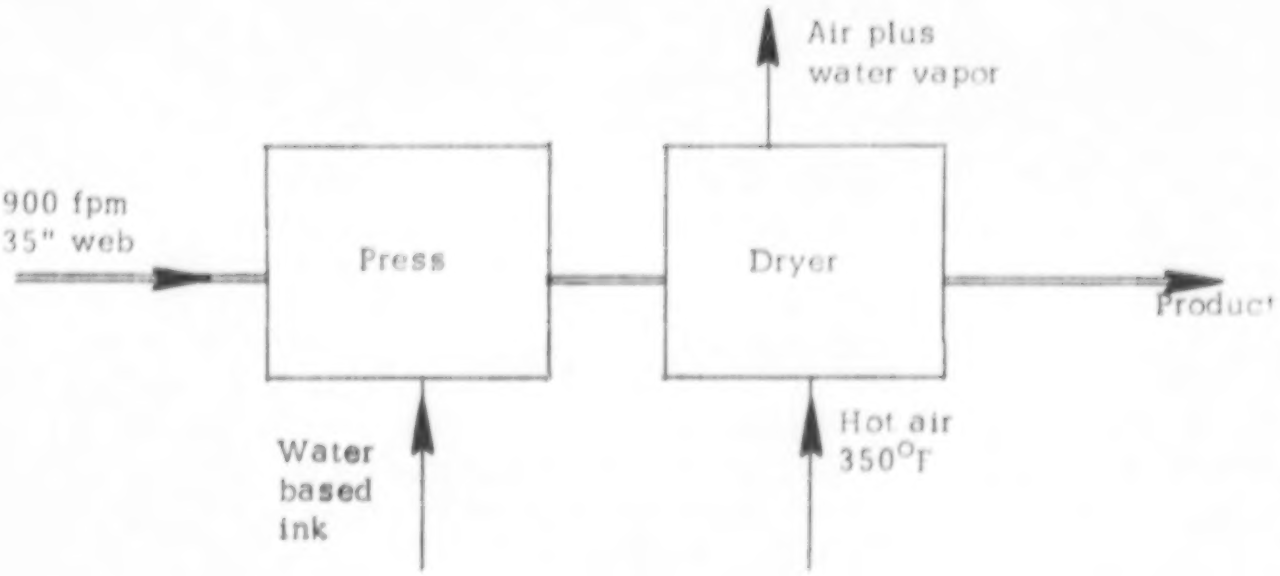

Air plus water vapor
900 fpm 35" web
Press
Dryer
Product
Water based ink
Hot air 350°F

Figure 26

Flexography, Water Based Inks

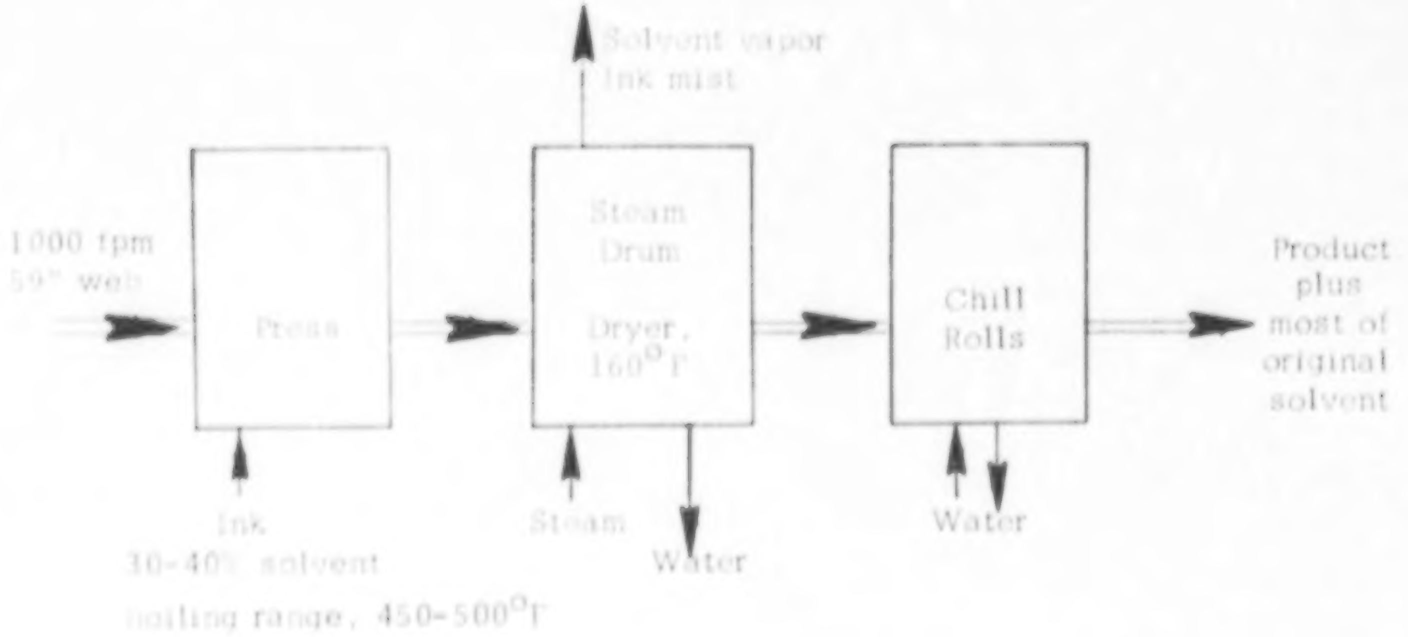

Solvent vapor
Ink mist
1000 fpm
59" web
Press
Steam
Drum
Dryer,
160°F
Chill
Rolls
Product
plus
most of
original
solvent
Ink
30-40% solvent
boiling range, 450-500°F
Steam
Water
Water

Figure 27

Rubber Plate Letterpress, Pocketbook Publication

The amount of organics exhausted into the air again depends on the type of ink used. Water colors may be used in this process for posters or water based emulsions may be used for fabric printing. In these cases there is no significant organic effluent. If oleoresinous poster inks (or paints) or alkyd enamels are used, the percent solvent will be low and effluent will be insignificant. These last two inks may be air dried, or the alkyds may be baked.

6.61 Screen Process - Lacquer Inks

The inks which do cause a significant amount of effluent are fast drying lacquers. These contain volatile solvents, generally in amounts considerably less than gravure and flexo inks. Figure 28 shows that evaporation takes place during printing and in the dryer, if one is used. No information about the percent solvent removed in each operation was obtained. If the product is air dried, it is expected that solvent will continue to evaporate in the drying racks even after the ink is dry enough to overprint. A study on solvent retention in poly(methyl methacrylate) films - not inks - revealed 6.6% residual toluene solvent after six months air drying (50).

6.7 Summary of Solvent Flow Charts

In an attempt to summarize information contained in the solvent flow charts (Figures 9 through 28) and related narrative sections of the report, Table 35 was prepared. The table presents by process the process variables and those sections, figures and tables of the report where the process is described. The table also brings under one heading, emission rates calculated from the stated process variables where these have been determined. By means of a "product solvent control" column, data relative to an estimated percentage of initial solvent remaining with the product are included where applicable. In the cases where data is either unknown or not available the abbreviation n.a. is shown. While Table 35 provides a means for easily comparing processes it should be used subject to the qualification given.

The flow diagrams show all new or innovative techniques in air pollution control which are presently feasible. However, some ways of reducing organic emission, such as the use of low-solvent inks, do not change the basic flow chart, and therefore, are not given a separate figure. Some of the newer film drying methods such as microwave are still in the experimental stage and, therefore, are not listed as possible installations.

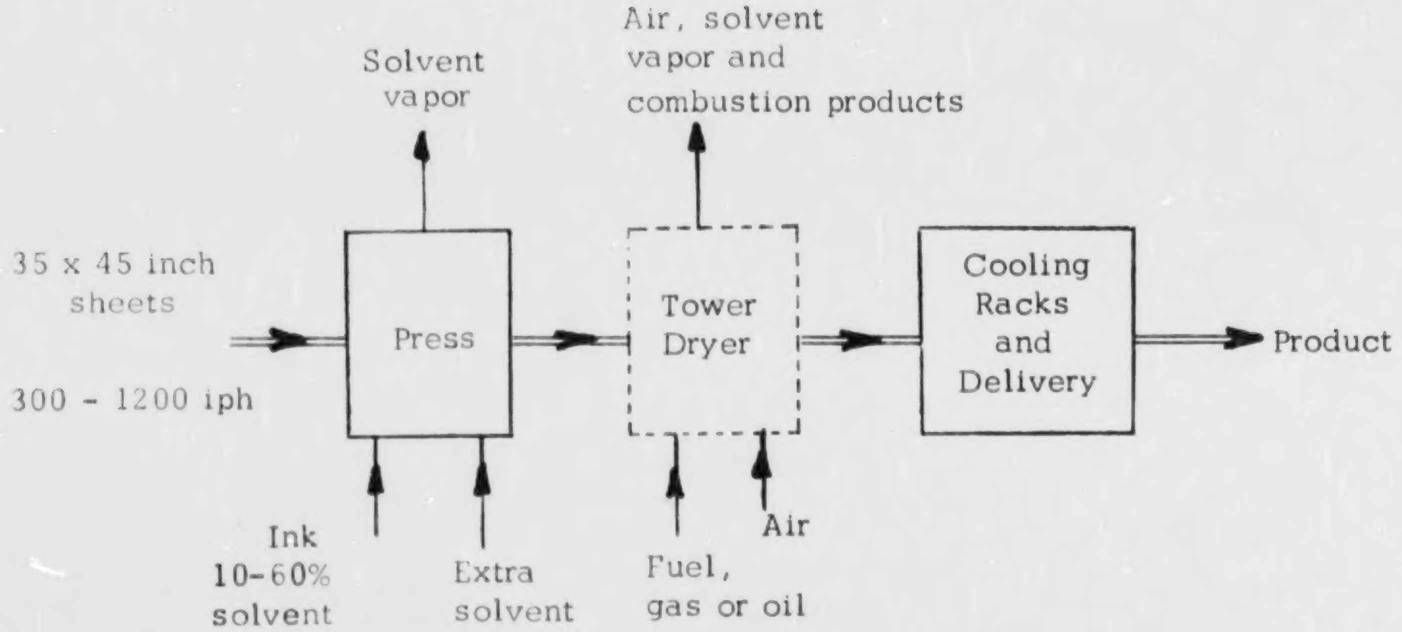

Air, solvent vapor and combustion products
Solvent vapor
35 x 45 inch sheets
300 - 1200 iph
Press
Tower Dryer
Cooling Racks and Delivery
Product
Ink 10-60% solvent
Extra solvent
Fuel, gas or oil
Air

Figure 28

Screen Process, Sheetfed - Lacquer Inks

TABLE 35

ABSTRACT OF PROCESS FLOW CHART INFORMATION

Process	Report Location	*Process Variables	Product Solvent Control	Emission Rate (lb/min)
Web Offset Publication	Section: 6.1, 6.11 Figure: 9	Ink Type: Heatset; 30-40% aliphatic solvent Ink Rate: 58-92 lb/hr for two sides Coverage: 4 or 5 colors; 1 or 2 sides Web width: 38" Speed: 1000 fpm	40%	n.a.
Web Publication Letterpress	Section: 6.21 Figure: 12	Ink Type: Heatset; 30-40% aliphatic solvent Ink Rate: 43-65 lb/hr Coverage: 200% Web width: 38" Speed: 1500 fpm	40%	n.a.
Web Offset Newspaper	Section: 6.12 Figure: 10	Ink Type: Oxidative drying 5% solvent Ink Rate: 6 lb/hr Coverage: 10% Web width: 38" Speed: 500 fpm	100%	n.a.

*All quantities shown have been used solely for the purpose of illustration and are not necessarily representative of typical activity.

Table 35 cont'd.

Process	Report Location	*Process Variables	Product Solvent Control	Emission Rate (lb/min)
Sheetfed Offset	Section: 6.13 Figure: 11	Ink Type: Oxidative drying 5% aliphatic solvent Ink Rate: 5 lb/hr Coverage: 80% Sheet Dim: 25" x 38" Speed: 4000 iph	100%	n.a.
Sheetfed Letterpress	Section: 6.23 Figure: 14	Ink Type: Oxidative drying 5% aliphatic solvent Ink Rate: 7.5 lb/hr Coverage· 80% Sheet Dim: 25" x 38" Speed: 4000 iph	100%	n.a.
Web Newspaper Letterpress	Section: 6.22 Figure: 13	Ink Type: 85% oil, 15% carbon no solvent Ink Rate: 4.5 lb/hr per unit Coverage: -- Web width: 30" Speed: 1000 fpm	No solvent used in process	n.a.

*All quantities shown have been used solely for the purpose of illustration and are not necessarily representative of typical activity.

Table 35 cont'd.

Process	Report Location	*Process Variables	Product Solvent Control	Emission Rate (lb/min)
Metal Decorating Inside Can Coating	Section: 6.3, 6.31 Figure: 15 Table: 33	Sheet Dim: 28" x 35" Rate: 90 sh/min Coating: Thickness: 20 mg/4 sq in Dryness: Essen. 100% Density: (solvent mixture) 0.83 gm/cc Solvent Coverage: 47 mg/4 sq in	n.a.	2.29 (8.9% L.E.L., see Table 33, Section 6.3)
Metal Decorating Outside Can Primer	Section: 6.32 Figure: 16 Table: 33	Sheet Dim: 28" x 35" Rate: 90 sh/min Dryness: 100% (ref. 50) Coating Thickness: Vinyl: 8 mg/4 sq in White Primer: 48 mg/4 sq in	n.a.	Vinyl: 1.54 (5.8% L.E.L., see Table 33, Section 6.3) White Primer: 3.5 (10.3% L.E.L., see Table 33, Section 6.3)

*All quantities shown have been used solely for the purpose of illustration and are not necessarily representative of typical activity.

Table 35 cont'd.

Process	Report Location	*Process Variables	Product Solvent Control	Emission Rate (lb/min)
Metal Decorating Printing Line	Section: 6.33 Figure: 17	Sheet Dim: 28" x 35" Rate: 60 sh/min Coating Thickness: 12 mg/4 sq in Ink: 5% aliphatic solvent; 50% solvent in varnish	n.a.	Varnish rate: 0.39 (1.5% L.E.L., see Table 33, Section 6.3)
Metal Decorating Inside Can Coating	Section: 6.34 Figure: 18 Table: 33	Coverage: 15,250 sq in/min Coating Thickness: 25 mg/4 sq in Rate: 24,000 cans/hr	n.a.	0.52 (2.6% L E.L., see Table 33, Section 6.3)
Label Varnishing	Section: 6.35 Figure: 19 Table: --	Solvent Content (dust dry): 5% Solvent in Varnish: 20%	n.a.	n.a.
Outside coating of Collapsible Tubes	Section: 6.36 Figure: 20 Table: --	Solvent Content of Ink: less than 5%	n.a.	n.a.

*All quantities shown have been used solely for the purpose of illustration and are not necessarily representative of typical acitivity.

Table 35 cont'd.

Process	Report Location	*Process Variables	Product Solvent Control	Emission Rate lb/min
Aluminum Can Coating	Section: 6.37 Figure: 21	Coating Thickness: no information Solvent Content of Varnish: no information	n.a.	n.a.
Gravure Rotogravure	Section: 6.4, 6.41 Figure: 22 Table: 34	Ink Type: 66% solvent Ink Rate: yellow: 4.5 lb/min others: 2.25 lb/min Coverage: 50% on coated paper Web width: 63" Speed: 1500 ft/min	n.a.	yellow: 3.0 (38% L.E.L.) others: 1.5 (19% L.E.L.) (See Table 34, Section 6.41)
Sheetfed Gravure	Section: 6.42 Figure: 23	Ink Type: Contains 55% solvent Sheet Dim: 29"x 43" Speed: 4500 iph	n.a.	n.a.

*All quantities shown have been used solely for the purpose of illustration and are not necessarily representative of typical activity.

Table 35 cont'd.

Process	Report Location	*Process Variables	Product Solvent Control	Emission Rate (lb/min)
Flexography Solvent Inks	Section: 6.5, 6.51 Figure: 24 Table: 34	Ink Type: 66% solvent Ink Rate: yellow: 1.32 lb/min others: .66 lb/min Coverage: yellow: 50% others: 25% Web width: 35" Speed: 600 ft/min	n.a.	yellow: .888 (42% L.E.L. others: .444 (21% L.E.L. (See Table 34, Section 6.41)
Flexography Steam Set	Section: 6.52 Figure: 25	Ink Type: Steam set	n.a.	n.a.
Flexography Water based	Section: 6.53 Figure: 26	Ink Type: Water based	n.a.	n.a.
Rubber Plate Letterpress	Section: 6.54 Figure: 27	Ink Type: 30-40% solvent	n.a.	n.a.
Screen Printing	Section: 6.6 Figure: 28	Ink Type: 10-60% solvent in lacquer inks	n.a.	n.a.

*All quantities shown have been used solely for the purpose of illustration and are not necessarily representative of typical activity.

6.8 Fate of Solvents as Reported in Survey

In an attempt to combine solvent use in the industry as reported in the survey with the fate of solvents as depicted in flow diagrams of the various processes (Figures 9 to 28), Table 36 was prepared*.

Only solvents presented in Table 10 (Section 2.44) could be utilized for this purpose. As stated in Section 1.11 and illustrated in Table 10a in Section 2.44, many plants are multi-process. Where both use and quantities used were not specified by process, distribution estimates were impossible. Therefore, correlation was limited to those plants involved in one process, or multi-process facilities where solvents could be assigned. For instance, many plants print by both letterpress and lithography, but fountain solutions are used only in the latter. Therefore, alcohol used in fountain solutions could be assigned to lithography.

Evaluation of solvent fate as tabulated in the last three columns of Table 36 are estimates only, based on extremely limited analytical studies which in no case are associated with the specific operations included in the solvents survey. As a consequence the solvent distributions represent the only estimates that are available.

*p. 130-131

TABLE 36

FATE OF SOLVENT BY PROCESS
(Based on Survey Data*)

Process	Solvent Series**	Use***	Amount Used[a]	Amount Recovered[a]	Amount in Product[a]	Amount Incinerated[a,g]	Unaccounted for[a]
I Gravure	0-	2x	97	>8500[f]	10620[h]	315	<82759
Figure 22-23[c]	0-	10	9992				
	1-	10	24017				
	1-	2x	620				
	2-	10	12495				
	2-	2x	373				
	0-to 2-	in ink[i]	54600				
Total			102194	>8500[f]	10620[h]	315	<82759
II Metal Decorating	0-	40	5739	-	459	950	4330
Figure 15-18, 21[c]	1-	40	9152	-	762	1510	6880
	0-	2x	5029	-	-	-	5029
	0-	10	1522	-	121	253	1148
	1-	2x	10416	-	-	-	10416
	2-	10	133	-	11	22	100
	2-	40	8179	-	654	1355	6170
	2-	2x	1963	-	-	-	1963
	0-	C-V[e]	38800	-	3492	7014	28294
	1-	in ink[i]	495	-	-	89	406
Total			81428	-	5499	11193	64736
III Flexography	0-	10	56	-	-	14	42
(all techniques)	0-	2x	2	-	-	-	2
Figure 24-27[c]	1-	10	583	-	146	-	437
	1-	2x	23	-	-	-	23
	2-	10	8544	-	2136	-	6408
	2-	2x	1636	-	-	-	1636
	2-	40	450	-	112	-	338
	1-, 2-	in ink[i]	12700	-	2540	-	10160
	1-, 2-	C-V[e]	785	-	-	-	785
Total			24779	-	4934	14	19831
IV Lithography	0-	10	1118	-	-	61	1057
Figure 9, 10, 11[c]	0-	2x	436	-	-	-	436
A. Heatset lithography[b]	0-	60	529	-	-	-	529
	1-	2x	199	-	-	-	199
	0-, 1-	60	640	-	-	-	640
	2-	2x	6	-	-	-	6
	2-	30	4659[d]	-	-	-	4659
	0-, 1-	in ink[i]	3880	-	1552	210	2118
	1-	C-V[e]	610	-	-	-	610
Sub-total			12077	-	1552	271	10254
B. Sheet-fed offset	0-	40	396	-	-	-	396
	0-	2x	159	-	-	-	159
	0-	60	44	-	-	-	44
	1-	10	18	-	18	-	-
	1-	40	346	-	346	-	-
	1-	2x	2033	-	-	-	2033
	1-	60	1041	-	-	-	1041
	2-	2x	702	-	-	-	702
	3-	2x	38	-	-	-	38
	1-	in ink[i]	815	-	815	-	-
	1-	V[e]	268	-	-	-	268
Sub-total			5860	-	1179	-	4681
C. Web offset, newspaper	1-	in ink[i]	275	-	275	-	-
	1-	2x	96	-	-	-	96
Sub-total			371	-	275	-	96
Total			18308	-	3006	271	15031

Table 36 cont'd.

Process	Solvent Series**	Used***	Amount Used[a]	Amount Recovered[a]	Amount in Product[a]	Amount Incinerated[a,g]	Unaccounted for[a]
V Letterpress	0-	10	34	-	14	-	20
Figure 12-14[c]	0-	2x	43	-	-	-	43
A. No newspaper	0-	60	11	-	4	-	7
	1-	2x	437	-	-	-	437
	2-	2x	77	-	-	-	77
	2-	40	30	-	12	-	18
	0-to 2-	60	242	-	97	-	145
	3-	2x	52	-	-	-	52
	0-	in h.s. ink[i]	8950	-	3580	-	5370
	1-	in n.h.s. ink[i]	526	-	526	-	-
Sub-total			10402	-	4233	-	6169
B. Newspaper	0-	2x	10	-	-	-	10
	1-	2x	7	-	-	-	7
		in ink[i]	none	-	-	-	-
Sub-total			17	-	-	-	17
Total			10419	-	4233	-	6186
VI Screen	0-	10	46	-	-	-	46
(all)	0-	2x	15	-	-	-	15
Figure 28[c]	1-	10	85	-	-	-	85
	1-	2x	123	-	-	-	123
	1-	40	6	-	-	-	6
	2-	10	48	-	-	-	48
	2-	2x	37	-	-	-	37
	0-to 2-	in ink[i]	188	-	28	-	160
Total			548	-	28	-	520
Grand Total			237676[j]	>8500[f]	28320	11793	<189063[f]

*Solvents (not in inks) limited almost exclusively to Table 10 (single process) data, series 0-, 1- and 2-. Quantities (Table 10) represent approximately 55% of grand total (Table 10a). See also Section 6.8.

**0-Series: aromatics, unsaturates, heatset ink oils
1-Series: essentially aliphatic
2-Series: oxygenated compounds (alcohols, esters, ketones, etc.)
3-Series: chlorinated compounds
(See also Section 2.441)

***10: Added to ink before using
2x: Washes
30: Fountain solution additive
40: Coating and varnish thinner
60: Miscellaneous
(See also Section 2.442)

a. Hundred gallons.
b. All lithography using heatset ink, exclusive of metal decorating.
c. Figures are based on hypothetical examples of processes applied to given product groups which require both process and solvent variations. Solvent survey data were obtained from actual industrial process operations without regard to product group.
d. Includes that used in sheet-fed lithography; use confined to litho.
e. In coatings and varnishes.
f. One plant only; calculated from efficiency factor estimated by respondent. No recovery data from other plant reporting adsorption equipment.
g. In thermal or catalytic combustion equipment. An engineering estimate of 90% conversion efficiency of the solvent by the equipment was used.
h. Figure based on engineering estimate.
i. Not adjusted for quantities reported "made-in-plant," which makes this value higher than actual.
j. Includes calculated quantities in inks and approximately 55% of additional amount reported used; see * above.

7.0 CONTROL TECHNIQUES

7.01 Introduction

In order to understand air pollution control equipment and its application to the graphic arts processes, it would be well to review the classification of pollutants as presented in Table 20 (Appendix C). There are three general approaches to the problem of controlling gaseous emissions from the printing and metal decorating industries: the first is process modification, the second, a change of process materials and third, the usage of air pollution control equipment.

7.1 Control by Modification of Processes

A process may be selected or the equipment modified so that no contaminant, or a minimum quantity of contaminant, is released. Here the printing and metal decorating processes could be modified in two areas: (a) process control and (b) equipment modification.

7.11 Process Control

Ordinary material and process variations such as ink and paper, press speeds and dryer operation present a multiplicity of interactions capable of emission generation. There are many types of inks used within and among the various printing processes, different substrates upon which printing is done, and an ever-increasing number of devices designed to accelerate or improve the drying system.

Improved control of the various material and process variations and other factors in the printing and metal decorating processes hereto not considered from an air pollution point of view, will require closer evaluation. Proper housekeeping procedures have to be followed. This point cannot be over-emphasized.

Although the solvents in the printing ink are suspected as the major contributor to air pollution, this is only partially true. Paper is part of the problem, ink is part of the problem and so is an improperly adjusted gas burner in the dryer and afterburner. Paper and ink are not chemically inert, and when contacted together in a hot dryer medium, the paper, the paper coating, the ink, the solvent, and other ingredients of the ink vehicle combine to give off an emission capable of creating air pollution. The problem is further compounded by the use of different paper grades and weight and the use of select ink formulations.

The necessity exists that each possible material contributor to the make up of the emission must be scrutinized. To this end, even poor combustion of natural gas may be responsible for some of the problem.

7.12 Equipment Modification

A second phase in process modification is one in which changes in ink formulation are somewhat greater and where some equipment changes will be required. Conventional presses will still be utilized. A potential example of an equipment modification is the use of the reverse lithographic process for the printing of glycol type inks (51).

In this process a special plate must be used on which the image area is wetted by a water miscible ink while in the presence of a volatile hydrocarbon solvent which wets the non-image area. The use of this process would eliminate the necessity of having hydrocarbons present in the ink. However, the dampening system would probably have to be enclosed so that fumes from the hydrocarbon fountain solution could be vented and treated to avoid air contamination from that source.

A new concept in printing termed "Driography" permits lithographic printing without a dampening system (52). The "dry" printing concept is based on a new photo-sensitive printing plate which eliminates the need for water or fountain solutions on a lithographic press.

The new process uses a "differential adhesion" technique where ink adheres to the image, but not the background. The dry plate will require a different ink than those currently used in conventional offset printing which are of necessity viscous and tacky. One distinct advantage is that the dry plate can be used with almost any type of paper particularly so with those papers that are usually adversely affected by normal blanket moisture from dampening solution. Like so many other products that have been produced for the graphic arts industry, the suggested and eventual use of these new advances lies with the industrial manager and his staff.

Another approach to equipment modification is in the drying cycle. Printing processes that employ drying ovens use a combination of flame and high-velocity air, heated air alone, or steam in the drying cycle. The best system for a given press depends on a variety of factors, including paper stock being used, ink chemistry, and press speed. Like other auxiliary units, the dryer must be tailored to individual pressroom requirements.

In several of the printing processes, the dryer plays a major role in the process, and therefore, commands a majority of the attention from an air pollution point of view. The drying of an ink film is not a singular process or phenomenon, but a dynamic system which includes the ink itself, the substrate upon which it is printed, the way in which it is deposited, the ambient drying atmosphere and the drying device used. Investigation of drying, therefore, must take a systems approach if it is to yield useful results. There are many types of inks used within and among the various printing processes, different substrates upon which printing is done, and an ever-increasing number of devices designed to accelerate or improve drying — in short, there are many possible systems under study that may have a role to play in the pollution picture. There are several new potential drying systems: (a) radiation (electron beam) drying, a system of the future, (b) microwave drying and ultraviolet drying systems in the development stage and (c) infrared drying, a commercially available process.

In discussing ink "drying", differentiation must be made between setting and hardening. Setting is defined as the transformation of ink into a less fluid state in which it has little tack and will not "set-off" under conditions in the delivery pile. Hardening is the development of resistance to rub or abrasion. Although both transformations are required, there are many instances where setting only is required on the press and hardening can occur at a slower pace. This distinction is important because it determines in many cases whether a drying system under consideration has any possibility of success.

Another differentiation is that between drying mechanisms and drying techniques. The mechanisms describe the chemical and physical ways in which an ink dries and can be separated as outlined in Table 37(Appendix C). Techniques are the means used for achieving the above listed mechanisms. These can be separated into three classes as in Table 38 (Appendix C). From the above possibilities several drying techniques from an air pollution control point of view should be looked at a little closer.

1. Radiation (Microwave) Drying

Microwave drying is a process in which electromagnetic energy is applied to a material to raise the temperature of its volatile components, causing them to evaporate. The physical mechanism involves rapid molecular movements of polar molecules in a rapidly alternating electric field which results in a swift increase in temperature. Work to date has been concerned with drying of inks on newsprint with letterpress and offset presses, and gravure inks on coated stocks.

One potential advantage of microwave drying is in air pollution control (54). In gas-fired burners, the oxidation products of the gaseous fuel are added to the solvents and volatile products from the ink, and all of these products are discharged from the stack. With microwave drying, only solvents and volatiles are discharged. Also, the temperature of the exit gases from a microwave dryer generally will be lower than that of gas-fired burners.

In summary, the application of microwave drying for web offset and rotogravure processes has progressed beyond the development stage. Determining the parameters of equipment costs, operating costs, material costs, and the possibilities of obtaining improved product remain for planned investigation. As a cautionary note, there have been recent discussions of health hazards of microwaves with the possibility that radio frequency waves may be more efficient in drying and less hazardous.

2. Radiation (Ultraviolet) Drying

The mechanism in ultraviolet drying is essentially a free radical polymerization. The ultraviolet light creates free radicals in the prepolymer itself or in an initiator.

One potential advantage of ultraviolet drying is in reduction of air pollution. Ultraviolet drying requires a monomer based ink which is non-volatile and thus should result in no solvent discharge to the atmosphere.

Work to date on applying ultraviolet drying to web offset and sheet-fed equipment is considered experimental. The engineering of commercial units for existing and new presses is in the early developmental stage.

3. Radiation Drying (e.g. electron beam)

In conventional ink systems, the organic material which binds the colorant to the substrate is either a high molecular weight liquid such as a drying oil, or a solid resin and polymer dissolved in appropriate solvents. Conventional drying systems start with inks based on this principle and subsequently convert the vehicle to a "solid" state by removal of solvents (and/or some of the vehicle), by chemical reaction or by physical change of state. Radiation drying, by contrast, starts with low molecular weight monomers or "prepolymers" and converts these to solid films by electron-induced polymerization and cross-linking. No volatile solvent is present, no driers are used, and the vehicle is chemically unlike that of existing inks. Very little heat is generated and drying is very rapid, beginning immediately upon exposure of the ink to the electron beam (53). Not all resins polymerize with electron beams. At present, polyesters and acrylics are used commercially (54). These resins are blended with reactive monomers which cross-link on exposure to the electron beam. The effect of these monomers on the inking train rollers and plate lacquers must be considered in developing an ink to be cured by electron beams (54). One of the justifications for radiation curing lies in its potential for reducing air pollution. Only reactive monomers are used so that there is no deliberate volatilization of organic substances into the air.

The equipment costs are high, and since x-rays are produced when electrons strike the target, the unit must be shielded. Considering these costs and the need for developmental research on inks, this method of curing may be of value in continuous operations as on a web, but not for a sheet-fed press (54).

4. Infrared Drying

The technology of infrared radiation, its sources and applications probably are more familiar than any other system proposed for ink drying (54). The infrared region of the spectrum lies between the visible light and the microwave frequencies. It is the intermediate infrared (that area between the near and far infrared) area that is most commonly employed in technological applications.

Appropriate commercial electrically powered units are available which can provide infrared radiation at selective frequencies. Infrared drying units are being used on heatset letterpress printing with apparent success. One difficulty still to be overcome with infrared drying is that different colors absorb energy at different rates, darker colors to a greater extent and lighter colors to a lesser, resulting in spotty drying. Further progress depends on development of more sophisticated equipment, perhaps somehow compensating for the different effect infrared radiation has on different colors.

One of the advantages to infrared drying systems is that the drying of inks using infrared may be accomplished without emission of the solvent thus reducing the amount of air pollution.

7.2 Change of Process Material

By the substitution of materials used in the process, a reduction in air contaminants can result.

The possibility of change of process materials is currently receiving a great deal of research and development attention. Here we are proposing the use of inks and coatings which do not pollute the air and do not demand expensive effluent treatment.

The material of prime importance used in the basic printing process and the one that must be considered, from an air pollution standpoint, is the printing ink. Three types of components are common to most printing inks: pigment, which is the finely divided organic or inorganic material that imparts contrast and color; resins, usually organic resins and polymers, which serve as a binder between pigment and substrate and impart special qualities to the ink such as gloss and scuff-resistance; and solvent, the medium in which the binder is dissolved or dispersed to carry the pigment through the press and onto the substrate to be printed.

The viscosity (or conversely, the fluidity) of printing inks varies from a stiff, dense paste to very fluid materials. The fluidity is based on the requirements of each printing process. For example, in gravure printing, the image design is engraved as tiny cells on the printing cylinder surface and the ink must be fluid enough to fill these cells as it is transported and transferred to the paper. In letterpress and lithography, which employ surface printing plates, the ink is rolled onto the printing surface and must have the ability to adhere to the image areas and maintain the image fidelity when transferred to the paper. The ink must be viscous in order to resist image distortion to flow.

Gravure inks are made up of approximately half solvent(s) and half solids. The solvent is normally the type that evaporates rapidly at room temperature; however, the type of solvent depends on the application and substrate used. Gravure presses, therefore, require ventilation because of the quantities of solvent evaporating; as much as 0.5 pound of solvent per pound of ink put onto the paper can be exhausted.

The viscous inks used in letterpress and lithography can be divided into two categories based on the physical process used to convert the ink film from a liquid to a solid state. The inks are referred to as oxidative drying and heatset.

A. Very little and frequently no solvent is incorporated into oxidative drying printing inks. The vehicle usually consists of a polymeric alkyd varnish prepared from a dicarboxylic acid (e.g., phthalic anhydride), a polyol, (e.g., glycerol) and monomeric acids (e.g., linseed oil acids). The film converts to a solid by oxidative polymerization without the application of heat. Inclusion of high boiling solvents in quick-set inks causes the ink to gel rapidly when the solvent is absorbed by the paper stock but no heat is required. The oxidative drying processes require from several hours to as long as 48 hours depending upon other characteristics of the ink additives and the paper.

B. Heatset inks for letterpress and lithography are based on other types of vehicles. One or more resins are solvated and/or dissolved in a kerosene type solvent. When imprinted on paper, part of the solvent is selectively adsorbed precipitating part of the resin within the ink film. Most of the remaining solvent is removed during passage on the web through the dryer. The solid-solvent ratio in these types of inks is usually about 60 to 70% solids to 30 to 40% solvents.

It is noteworthy to mention that deodorized solvents are used in heatset inks where little or no odor is desired. A typical use would be in printing paper or other materials which will be used near or in actual contact with food products. Printers using these deodorized solvents have indicated to a solvent supplier a reduction in odor coming from the stack which they attribute to the fact that less oxidation products are formed. The deodorized solvent is a highly refined, odorless, aliphatic petroleum solvent. It is refined by the same method given USP mineral oils.

In graphic arts, the solvents serve as a part of the printing ink vehicle which provides the means for carrying colorants and generating contrast in the reproduction. Both vehicles and solvents vary widely in viscosity depending on the graphic arts process. The solvent content of inks and coating can range from none up to as high as 80% (55).

The initial phase of control by change of process materials has been established along the lines of formulation of inks and coatings using exempt solvents. Scientific findings (33) have shown that certain hydrocarbon solvents combined with nitrogen oxides in the presence of ultraviolet light (sunlight) produce a photochemical smog of the type prevalent in the Los Angeles basin. The extent of the photochemical reaction varies with the type of hydrocarbon solvent emitted into the atmosphere. As would be expected, regulations have been established placing the greatest restriction on reactive ones (olefins, substituted aromatics and certain ketones) and exempting others from control. A summary of controls imposed by Los Angeles Air Pollution Control District Rule 66 and San Francisco Bay Area Control District Regulation 3 can be found in Table 39 (Appendix C). Under these regulations, an exempt solvent is one which is not within the definition of photochemically reactive as described in the table. Los Angeles Rule 66 (Regulation 3 of San Francisco basically follows the same form with one or two exceptions) recognizes three distinct categories in the drying of inks and coatings.

(1) Coatings baked, heat cured or heat polymerized, regardless of the type of solvent used, fall into the first category.

(2) Air-dried coatings in which photochemically reactive solvents are used are in the second category.

(3) Non-reacting systems using non-photochemically reactive solvents, whether baked or air-dried, are in the third.

In the first category, no more than 15 pounds of material may be emitted into the air per day from each operating setup (i.e., each spray booth, dip tank, curtain coater, oven, etc. This does not mean 15 pounds per plant).

The second group is limited to 40 pounds per day from each operating setup and the third category has no limitations placed on it by the law.

Operations covered in the first two categories are given an option, however. If they can reduce these organic emissions by 85% or to not more than 15 pounds and 40 pounds respectively, they can exceed these specified limits. This may be accomplished by use of incineration equipment. When emissions are incinerated the process must reduce at least 90% of the residue to carbon dioxide, since inefficient combustion can be worse than no control at all.

Whereas Rule 66 affects all printers in Los Angeles, Regulation 3 in San Francisco places restrictions on rotogravure printers only. Gravure inks, classified as types A, B, C, D, E and T have solvents which range from exempt to non-exempt. The following is a brief description of gravure type inks:

1. "A" Type

   Employ predominately aliphatic solvents which are paraffinic in structure, i.e., normal, iso-, and cycloparaffins. Since only small amounts of aromatics are present, this type of ink does not present a problem.

2. "B" Type

Normally employ 50% aliphatic hydrocarbons and 50% aromatics (i.e., toluene or xylene). This is no longer permissible under Rule 66. Toluene or ethylbenzene may be used up to 20% with the rest of the solvent consisting of exempt ketones, alcohols, or esters.

3. "C" Type (divided into two groups "a" and "b")

"a" Group - 50% ester or ketone and 50% aromatic. The aromatic content must be placed within exempt limits.

"b" Group - 67% ester or ketone and 33% aliphatic hydrocarbons. The branched ketones must be kept to the 20% limit.

4. "D" Type (divided into two groups "a" and "b")

"a" Group - 50% alcohol (ethyl or isopropyl) and 50% aliphatic hydrocarbons. Presents no problem.

"b" Group - 30% alcohol (ethyl or isopropyl) and 70% aromatics. Not acceptable. Will require that some aromatics be replaced by oxygenated compounds allowing the use of some aliphatic hydrocarbons.

5. "E" Type

Employs almost exclusively by 100% alcohols (ethyl); therefore, no restrictions.

6. "T" Type

Utilize 100% aromatics (toluene or xylene) with chlorinated rubber and will require replacement of all but 20% of the aromatic with strong polar compounds, possibly ketones or esters.

Solvent substitution can be made in some cases for aromatic hydrocarbons; however, difficulty is encountered in obtaining exempt types with solvent power equal to those of the aromatic hydrocarbons. Aromatics are the strongest of all hydrocarbon solvents but in general are classed among the worst smog formers.

P

Naphthenes have intermediate solvency and the paraffins are the weakest, and the least objectionable as far as smog is concerned (56). Possible substitutes under Rule 66 are saturated alcohols, esters and ether-alcohols, all of which are exempt (56).

The ketones as a class can also be considered, however, application can be limited depending upon chemical structure. Methyl ethyl ketone and cyclohexanone are two which are entirely exempt. Mesityl oxide and isophorone, on the other hand, are restricted to 5% because they are olefinic. The high-boiling ketones, methyl isobutyl, methyl isoamyl, and diacetone alcohol are limited to 20% because they are branched. Acetophenone is not specifically declared in Rule 66 but may be classified as a C_8 aromatic and as such would be restricted to 8%.

Considerable experimentation will be necessary as polar compounds are introduced as replacements for both toluene and xylene (57). The usual solvency parameters applied to hydrocarbon solvents will no longer be applicable to mixed solvent with functional properties and behavior taking on increased importance (57).

Flexographic inks use primarily alcohols, esters and aliphatic solvents, which are exempt under Rule 66 (51). News inks which dry by absorption into the stock are not affected by Rule 66. Inks and coatings applied by offset and letterpress which contain high-boiling hydrocarbons and are dried by ovens or direct flame are subject to Rule 66 and the use of exempt solvent will not excuse them. Therefore, solvent reformulation is only a partial answer.

Current press speeds on commercial web letterpress are about 1800-2000 feet per minute, web offset presses around 1000-1200 feet per minute, gravure presses at 1200-1500 feet per minute and operation speed of flexographic presses near 800 feet per minute. Throughout the years, ink manufacturers have developed inks that have kept pace with those press speeds. However, it is now clear that a crossroads is being approached, and that further progress in printing, outside of entirely new reproductive processes, to combat pollution may lie in new methods of drying.

The solvent type inks present no problem as far as drying speed is concerned with possibly press stability entering the picture; the main difficulty is air pollution. One approach for total elimination of hydrocarbon effluent is through the use of aqueous inks. Aqueous vehicles are quite feasible for use in many types of inks and coatings. Some flexographic inks presently in use are water-based. Gravure inks for publication printing on news stock have been field tested but one authority states that water-based publication gravure inks are some eight years distant. Both water soluble polymers and latex dispersions increasingly are being used in coatings. Aqueous inks are considered to be feasible for letterpress and have a potential use in the reverse lithographic process.

Perhaps the greatest limitation of aqueous systems is the high heat of vaporization which seriously limits production rates and the low gloss of dried films. A possible solution to this limitation is to employ microwave drying. Aqueous inks can be dried in a fraction of a second, holding a promise of even higher press speeds than are obtainable with conventional solvent inks (51). Another interesting feature with microwave drying is that the web temperature is very low, probably not exceeding 200°F. At this temperature it is unlikely that an odorous reaction product will be formed in the dryer. It should be noted than in the application of microwave drying of water-based inks as opposed to solvent-based inks different wave lengths are used.

Several printing ink laboratories visited during the field trips are expending effort to accomplish drying at high speeds and still solve the air pollution problem. The work includes spraying a water solution of a resin on sheet-fed presses to speed setting.

Another approach is a chemical bath which would harden and dry the inks as the web passes through it. Still another approach is incorporating a catalytic agent in the paper that would react with the ink and lastly, a "two-pot" ink with two chemicals reacting with each other to induce solidification.

Ink manufacturers as well as electronic equipment manufacturers are studying electric energy as a means of drying inks; these systems were discussed earlier; namely, infrared, electron beam and microwave drying.

A more current approach and one undergoing extensive developmental work, is the low-solvent ink or the so-called "solventless" inks. A few major ink manufacturers are presently marketing this type of ink, with its application aimed at web offset and web letterpress equipment. In conventional heatset inks, resin-solvent vehicles are used to transport color pigment onto the printed surface. The solvent makes a limited contribution to the visual appearance of the ink and must be removed in order for the film to dry. This is accomplished by passing the printed sheet through large drying ovens in which solvent is emitted as a vapor into the atmosphere. These "solventless" inks are apparently based on the property that allows drying by a thermally induced chemical reaction. The polymerization reaction occurs at relatively low temperatures and is claimed by several ink manufacturers to reduce appreciably or eliminate the smoke and potential odor presently attributed to heatset printing press operations. This reaction, it is further claimed, allows the ink to dry at normal press speeds with what is reported to be negligible effluent discharge.

The absence of solvents in these inks, according to the manufacturers, means a reduction in oven condensation, smaller drying ovens and reduced operating and maintenance costs. Further, the ink can be used on present press equipment and has no detrimental effect on the rollers or plates now in use. Pre-printing preparations also are unaffected and comparable to those employed with conventional inks. Several tests using these inks on present press equipment have been accomplished with little or no reportable data. Some developmental problem areas, especially gloss, sharpness of printing and quality have been encountered by the ink manufacturers, however, recent statements by ink manufacturers indicate that the gloss is up to commercially acceptable standards. Even if the latter statements are optimistic, the approach represents a positive solution to the air pollution problem. In the absence of disclosure of specific composition, this ink can be a prepolymer or mixture which further polymerizes at temperatures up to 270°F.

In addition to aqueous inks and solid state (low solvent) inks, another approach is that of catalyzed inks. Possibly the best way to explain catalyzed inks is to differentiate between conventional inks and a catalyzed system. Conventional inks are made up of pigment, resins (either singly or in combination) plus solvent. These inks set by simple evaporation of the solvent, depositing on the sheet a layer of resin impregnated pigment. Catalyzed systems, on the other hand, are made up of pigment, resins (always in combination), solvent, and a catalyst usually added to the ink just before printing (58). The setting and drying occurs in two separate steps. The first is the normal evaporation of the solvent which is then followed by the cure resulting in polymerization (58). Use of this type of system will undoubtedly impose on press personnel the need to use some different techniques. Rigid specifications sparked by the pollution problem are forcing conventional ink system vehicles close to the limits of their performance capabilities. Catalyzed systems may be capable of resetting the limits on performance and improving the pollution problem. Since everything has a price, so also will new standards take their toll on the printing system. Catalyzed inks will require dealing with reaction products which are by-products of the polymerization reaction, slow press speeds on some jobs, purchase of efficient curing equipment and its subsequent higher cost in generating higher heat, to mention a few.

7.3 Control by Incineration

Having considered control techniques along the lines of process modification and change of process materials, an additional technique would be to install air pollution correction equipment to treat dryer exhausts so as to eliminate air contaminants either by incineration or by solvent recovery. Three avenues of proven control methods are available to the printer and the metal decorator; other means to control have received some evaluation for industry application, and are included to make the report as complete as possible. Two types of incineration, thermal and catalytic, are discussed along with the adsorption (solvent recovery) system.

Incineration of solvents and fumes either by thermal or catalytic means into carbon dioxide and water provides an answer to the air pollution problem. It is an established fact that under proper incineration conditions, hydrocarbons, solvents, and the inorganics are oxidized. However, even with the high efficiencies of this type of equipment, incineration is not 100% effective. Although some of the high cost of operation of incineration equipment can be offset by heat recovery units, both capital cost and operating costs are substantial.

7.31 Thermal Incineration

Thermal incineration (commonly referred to as direct flame) involves direct burning of the effluent in a gas-fired incinerator. Although simple in concept and operation, there is actually a great deal of design, engineering and manufacturing skill involved. The combustible elements in the effluent stream must be raised to their auto-ignition temperature in the presence of sufficient oxygen to complete the chemical reaction and they must be held at that temperature for a sufficient length of time to permit the chemical reaction to occur all the way through to CO_2 and water vapor (59). This time-at-temperature factor is very important, for not carrying the oxidation to completion will result in products of incomplete combustion that may be more offensive than the pollutants being consumed. Figure 29 (Appendix B) illustrates how typically used printing and metal decorating solvents when subjected to various intermediate oxidation stages can create offensive odors of increased intensity (60).

The process of thermal incineration is outlined by the flow diagram shown in Figure 30 (Appendix B). The products from the press dryer enter the thermal system, may be preheated to 600°F to 900°F and then incinerated in the residence chamber at temperatures on the order of 1000°F - 1500°F. The fumes when properly incinerated evolve as carbon dioxide, water and heated air. Fuel costs can be held to a minimum through the use of a heat exchanger and through recirculation of heated air. The amounts of recirculation to be employed remain as individual installation requirements and can range from little or no circulation to a detailed complex heat recovery system indicated by dotted lines in the diagram.

The incineration process releases heat, which can be recirculated as outlined above and could even be utilized as part of the building heating system. An example of heat being used from the incineration process is the case of metal sheet coating ovens employing afterburner systems (without heat recovery). In this application the hot air from the afterburner is used directly to replace oven zone burners in the coating oven, thus decreasing operating and maintenance costs.

Compared with other control processes for organic emissions, direct-flame incineration is capable of achieving a high level of effectiveness. Experience has shown that direct-flame incineration systems can operate continuously at efficiencies at 90% to 99% (61).

A means to estimate the cost of flame incineration equipment including initial purchase cost, installation cost, and annualized cost of operation can be found in economic consideration section of this chapter.

7.32 Heat Exchangers

(Although heat exchangers are not air pollution control devices, they are being utilized effectively in heat recovery from printing plants and metal decorating operations.)

Normally a heat exchanger is designed to recover about 45-50% as usable heat for re-cycle to the system. If, for example, 1200°F is the outlet temperature of the thermal unit and 300°F is the outlet temperature of the dryer (inlet of the combustion unit), the recovery temperature of the heat exchanger probably would be:

$$\text{R.T.} = \frac{1200-300}{2} + 300 = 450^{\circ}\text{F} + 300^{\circ}\text{F} = 750^{\circ}\text{F}$$

It should be noted that a heat exchanger constructed of stainless steel tubes allows a higher recovery temperature than the 600-700°F temperature limit of carbon steels. The operating range of the stainless steel extends up to 900°F.

7.33 BTU Content of Printing Press/Metal Decorating Effluents

To heat 6000 scfm air from 300°F to 1200°F requires some 3.1 million Btu's per hour. Basis for this calculation is as follows:

Sp. wt. dry air (assuming temperature range 300°F-1200°F) = 0.04 lbs/ft^3

Sp. heat of dry air = 0.24 Btu/lb°F

Temp. differential = 1200-300 = 900°F

Therefore, the total heat required equals:

$$\text{Btu/hr} = 6000\ \text{ft}^3/\text{min} \times 0.04\ \text{lbs/ft}^3 \times 0.24\ \text{Btu/lb}^{\circ}\text{F} \times 900^{\circ}\text{F} \times 60\ \text{min/hr}$$

$$= 3{,}110{,}400$$

(Depending on the specific weight of dry air used, the amount of Btu's will vary. At 0.03 lb/ft^3 sp. wt. the amount of Btu's/hr is 2,268,000).

In discussions with air pollution control equipment suppliers it was learned that normal printing press dryer effluents can of themselves support combustion and raise the outlet temperature some 150°F. Keeping in mind the total temperature differential required (1200°F-300°F or 900°F), approximately 17% of the required heat is supplied by the press effluents. (A range of values between 10-20% for various printing press effluent can be expected, with 20-30% for metal decorating operations.)

Returning to the 6000 scfm unit, we see that the press effluents supply 1/6 of the 3.1 million Btu's per hour resulting in a savings of approximately one-half million Btu's per hour in heating costs. In this case, the remaining Btu's would have to be supplied by additional fuel to keep the combustion temperature at 1200°F.

7.34 Catalytic Incineration

Catalytic incineration is a chemical oxidation process differing only from the thermal in that combustion, which occurs in a catalyst bed, is flameless. A catalyst can best be described as a material which accelerates a chemical reaction without itself being changed in any way. Most catalysts now in use employ a platinum group metal deposited on an alumina pellet or honeycomb substrate or is electro-deposited on a metal ribbon. The process of catalytic incineration can be traced by referring to the flow diagram in Figure 31 (Appendix B). The products from the press dryer enter the catalyst system; are preheated to a temperature in the 600-900°F temperature range, pass through the catalytic element and emerge as carbon dioxide, water vapor and heated air. Fuel costs can be held to a minimum through the use of a heat exchanger and through recirculation of heated air. The amount of recirculation to be employed rests with individual requirements and can range from no recirculation at all to a highly efficient heat recovery system shown by the dotted lines in the diagram.

Theoretically, this is an ideal system and under most circumstances and proper maintenance it is. The chemical reaction releases heat, which can be recirculated as noted above and could even be utilized as part of the building heating system.

Efficiency of the process is good having been reported as being 85% to 95%, depending on the application.

The life of a catalyst is among other things dependent on the operating temperatures. At the 900°F temperature, the life is five years; at 1100°F the life is 3-4 years. Operating temperatures above 1100°F will reduce the life of the catalyst sharply. One drawback with the use of catalysts is the "poisoning" that may occur. (For a listing of these drawbacks, see Table 38 (Appendix C). Effluent from the press stream or oven exhaust must be free of lead, zinc and silicones. Organic solvents used in printing inks normally do not contain elements capable of poisoning a precious metal catalyst. There have also been some cases of clay plugging the catalyst bed — the clay resulting from the thermal degradation of certain paper. However, most catalyst poisoning and plugging that has been reported occurred on some of the first commercial applications of catalytic systems in the graphic arts. In recent years, the state-of-the-art advances in catalytic abatement have minimized most of the drawbacks which have been reported on the earlier examples.

Generally, the cost of a catalytic incinerator is higher than that of a thermal system but its operating cost may be lower since catalytic incineration occurs at a much lower temperature, (around 900°F) as opposed to thermal (around 1200-1400°F).

7.4 Control by Adsorption

Adsorption, the removal of a vapor from a gas stream into the surface of a solid without chemical reaction is an additional method of controlling solvent emissions. When a vapor-laden air stream is passed over a bed of activated carbon (commonly used in adsorption systems) the vapor molecules are adsorbed by the carbon (63). Subsequently, the vapor may be removed by a current of hot air or steam. (Typically, while one adsorption bed is recovering organic vapors from the effluent stream, another is being regenerated by the hot air or stream.) Steam usually is preferred.

Thus, solvent recovery is an attractive feature of the adsorption method. If a recovered solvent is not miscible with water, it can simply be separated by decantation; otherwise, the liquid mixture must be separated by distillation. An example of this type of solvent would be a water-soluble, oxygenated alcohol. The more complex the solvent mixture, the more involved the separation and thus the more costly the operation. Figure 32 (Appendix B) indicates a flow diagram of an activated carbon solvent recovery system. This recovery system would at minimum require a fan or blower to move the vapor-laden air, two drums containing a bed of activated carbon which would be used alternately (one adsorbing the other being regenerated), a condenser for condensing the desorbed steam and vapor and some sort of decanter to achieve the separation. Some controls would also be necessary to switch air flows to the absorbers and control the desorption steam.

There is a great deal of interest in solvent recovery for the rotogravure process, with the degrees of separation and recyle purity of solvents major economic factors. The principal factors to be considered in determining the economic feasibility of solvent recovery for a specific operation are:

1. Type of ink and therefore the solvent being utilized
2. Range of solvents being utilized on the same press
3. Specific dryer design and the volume of air to be handled
4. Recovered solvent quality
5. Make-up solvent requirements
6. Availability and cost of utilities, including steam, electrical power, cooling water and plant or instrument air

It has been proposed that single solvent ink systems would greatly improve the economics of solvent recovery (51). The use of single solvent inks in combination with a simple solvent recovery system yielding high grade recovered solvent might be economically advantageous even though the initial solvent cost would be higher (51).

Another alternative may be the return of the crude recovered solvent to the ink manufacturer who can then refine it for reuse.

There are potential difficulties in the use of charcoal adsorption solvent recovery systems, particularly where the ink or coating contains significant proportions of resins that are polymerized during the oven-drying or bake. The tarry polymerization by-products volatilized during the oven-drying or bake can foul the charcoal, thus decreasing adsorption efficiency and increasing the complications in recovering solvent of purity adequate for re-use. The extent of such difficulty will vary widely depending on the particular resin systems involved as well as the specific solvents used.

7.41 Activated Carbon for Pollution Control

Activated carbon can be used to remove organic vapors from a gas stream by adsorption (64). Although thick beds of activated carbon are the most efficient, thin beds are ordinarily specified so as to minimize pressure drop. There is a "rule-of-thumb" that about 1 lb of carbon is needed for every cfm going through the recovery unit. If the concentrations of the organic vapor are very low, this may be reduced to perhaps 1/4 lb/cfm. Another "rule-of-thumb" is that the carbon will absorb 10 to 20% of its own weight of solvent before it is necessary to desorb and start another cycle.

Several factors influence the capacity of a carbon bed for an organic solvent: (64)

1. Concentration - The bed will have increased capacity if the concentration of vapor in the gas stream is high.
2. Temperature - High temperature usually decreases a bed's capacity, while low temperature increases it.
3. Humidity - High humidity decreases capacity.
4. Velocity - Total capacity is little affected by velocity changes. However, as velocity increases, efficiency of removal drops because of the lessened time the gas is in contact with the carbon.
5. Solvent Boiling Point - High boiling points tend to decrease capacity.
6. Molecular shape and weight - Molecular weight has no effect, but molecular size and shape does.
7. Water solubility - A bed will have greater capacity for a material soluble in water if the bed is wet with water.
8. Bed depth - A deep bed generally has a greater capacity than the same quantity in a thin bed.
9. Contact Time - Other things being equal, the greater the contact time, the greater the capacity.

Although activated carbon has been used for many years to adsorb low concentrations of chemicals from air and process gas streams (e.g., solvent recovery) and has been used in a general sense to deodorize occupied spaces, its use as an independent air pollution control device is only slowly emerging. This has been primarily because the concentration of industrial air contaminants has been at such a high level that adsorption was not the most economic unit operation. Systems such as incineration, either direct flame or catalytic, have been the contaminant removal process. However, the picture is rapidly changing as air pollution control authorities are enforcing more stringent emission regulations.

Adsorption processes represent a possible new or novel approach to contamination control within the graphic arts industry. There are at least a half dozen novel regneration process schemes in development or demonstration stages at this time. The fact that no information is being published in this area does not preclude the fact that active research and development is being carried on.

7.5 Other Means to Control

7.51 Scrubbing

This term defines various types of abatement equipment that removes either particles or vapors from the air by the mechanism of liquid contact. Scrubbing has been attempted in the graphic arts industry with little or no reportable data. The fact that liquid scrubbing may or may not be a means of control applicable to the graphic arts industry remains to be seen. There is simply no data to substantiate its performance and effectiveness relative to the industry. Furthermore, there exists a serious threat to creating a water pollution problem which must enter into a practical engineering determination.

However, all possibilities should be considered because of the number of plants being cited for air pollution under the nuisance clause (state or local). The use of potassium permanganate in gas scrubbing equipment to remove impurities from gases is not a new one. This use has been employed in asphalt and rendering plants and has specifically been a method for removal of hydrogen sulfide and mercaptans.

Indications are that under proper conditions the use of this chemical would be an economical and effective means to destroy a large variety of odoriferous irritating materials ordinarily found in waste gases.

Potassium permanganate ($KMnO_4$) is a strong oxidizing agent. It will attack oxidizable matter under a wide variety of conditions; however, pH concentration, contact time and temperature must be considered important variables. In air scrubbing, the most practical pH is from 8 to 10, because most permanganate oxidations of organic compounds are catalyzed by hydroxyl ions. In the slightly alkaline pH range, permanganate will react with an oxidizable compound as shown in the following equation:

$$2MnO_4 + H_2O \xrightarrow[\text{agent}]{\text{reducing}} 2KOH + 2MnO_2 + 3[O]$$

The oxygen formed in this reaction does not appear in molecular form, but immediately combines with the reducing agent. Inasmuch as the pH is on the alkaline side, a secondary effect occurs in some deodorization reactions.

Any malodorous lower fatty acids formed by oxidation of the corresponding alcohols or aldehydes will be retained as odorless alkali metal salts in the scrubbing solutions. In alkaline and neutral solutions, $KMnO_4$ is non-corrosive to most commonly used scrubber materials.

Review of experimental data indicates that potassium permanganate solutions have a pronounced deodorizing effect upon a wide variety of odorous compounds (65).

7.52 Masking and Counteraction

An odor may be modified by the addition of other odorous matter under controlled conditions but not involve a chemical change. When such a modification is used for odor control, the process is called counteraction (a reduction of odor intensity), as opposed to masking (obscuring of the original odor).

As a means to control, this approach offers little to the graphic arts industry. Considerable thought should be given before using this approach to control.

7.53 Control of Pressroom Contamination

1. Electronic Air Cleaners

The problem of contaminated air within pressrooms cannot be overlooked. This contamination (dirt, paper dust, offset spray, smoke, and odors) is generated continually. Several systems have been developed utilizing an electrical neutralization method. Particles in the air may posses a positive charge, others a negative charge and still others may be neutral.

One such system employs the theory that most pressroom contamination contains carbon (to some degree), which is charged electrically positive and thus utilizes a negative charge to collect the contamination (66). The polarity neutralization method prevents pressroom contamination from returning to suspension and thus controlling the abrasive effect of dust particles, allowing moving parts of presses and other machinery to operate more efficiently, thus enabling reproduction quality to be increased and increasing the efficiency of the workers.

Still another system cleans pressroom atmosphere by charging all particles with a positive charge as they pass through a high-voltage ionizing screen. The charged particles are then attracted to and adhere to negatively charged collecting plates which form part of a series of parallel plates, charged alternately positive and negative. Periodically, depending on the dirt content of the air, the plates can be flushed through the use of spray detergent and the system regenerated for re-use.

Lastly, a third system, recognizing that electrostatic forces are present in a pressroom and that many machines and processes in the graphic arts industry produce very strong electrostatic fields in the working space neutralizes the air-borne contaminant for collection by filtration. A great deal of deposition of contamination on surface (floors, walkways, etc.) is a result of the build-up of space charge and surface static electricity within an occupied space. By preventing this build-up, air-borne particles are able to be removed from the pressroom air.

2. Ink Mist Eliminators

To date ink mist eliminators have been utilized exclusively in high speed letterpress newspapers. Basically an ink mist removal system contains some sort of intake manifold which draws contaminated air both on and into a filter (67). The ink removed from this system is drained to a receiving cylinder. High centrifugal forces created by fan-like action within the filtration unit promote considerable turbulence resulting in coalescence (colliding of small particles, creating larger ones). The larger particles formed develop enough energy as a result of their mass and velocity to collect on the outer walls of the filter. Here the fluid is simply drained to a collection. vessel.

This system requires simple maintenance that can be carried out by plant personnel. Building maintenance costs are reduced as walls do not require washing down, presses remain cleaner, and lighting is maintained at normal levels with bulbs and reflectors free of ink coatings. The system is presently confined to letterpress although other applications are being sought. With increasing concern for noise sources, these units are equivalent to a vacuum cleaner operating at half speed.

7.54 Dispersion Techniques

A. Stack Considerations

The first step in air pollution control should be to reduce contaminant discharge rates to a reasonable minimum by means of process modification, material change and the use of air pollution control equipment. The remaining contaminants can then be discharged to the ambient atmosphere in a manner which will provide maximum dilution and dispersion. Good stack design can meet these dispersion requirements, but stacks can provide only dispersion (68). In no way can they reduce the rate of contaminant discharge and a stack is no substitute for any of the above means of reducing contaminant discharge rates.

It should be further emphasized that careful attention must be given to final stack design, even with incineration equipment installed, to permit adequate dispersion of the effluent before reaching a potential receptor.

Stack design problems fall into two general categories, those of building re-entry and those of general area pollution. Re-entry of exhaust fumes has been a serious problem created by fans or stacks that discharge at or near roof level and further by the addition of weather caps on the end of stacks. These tend to trap the contaminants and increase the probability of re-entry, downwash, and excessive pollution of nearby areas.

Industrial Ventilation Manual of the American Conference of Government Industrial Hygienists should be consulted to provide a good basis for sizing and design to prevent this type of problem.

Effective stack design requires knowledge of air flow over buildings and the discharge of contaminants at various stack heights as shown in Figure 33 (Appendix B).

The following points should be kept in mind (68):

1. Air flow over a building creates a pressure zone on the upstream side and negative pressure zones (cavities) on the roof, lee side and other sides.

2. The height of the roof cavity is maximum when the wind is perpendicular to the upstream side. Thus, this is the design condition. Wind tunnel studies by a number of investigators indicate that for perpendicular flow, the height of the roof cavity for a cube will be approximately 1.5 times the building height; or, in terms of the height over the roof, the dimension will be 0.5 of the building height. For a higher structure of the same width, there would be no increase in cavity height over the roof. A shorter structure would have a lower cavity. A wider building, because of the greater interference to wind flow, would have a higher cavity dimension.

3. The contour height is that height above a building above which there is no further displacement of the air flow. For a simple block building, the contour height is approximately 2.5 times the building height. Discharge above the contour zone is very important for high emission rates, for highly toxic effluents and for nuisance effluents such as mercaptans, which have extremely low odor perception concentrations.

4. The size and shape of the building air flow contour zone and cavities remain relatively unchanged with changes in wind velocity. Only the pressures within these zones change. Several observers have pointed out, however, that because wind is turbulent it can be expected that the contour zone and cavity envelopes will be erratic in shape.

5. Rounding a building outline or using setbacks will decrease the heights of the contour and cavity zones over the high roof. This is of particular importance to the overall design of a building and stack.

6. Contaminants released at roof level may spread over the entire roof inside the cavity. Fumes carried over the lee side will be brought into the ground, back to the building, and may even flow up onto the roof. Such contaminants will enter nearby ventilation intakes, frequently in unacceptable concentrations.

7. Topography and nearby structures may disturb the air flow contours around a building and create very unfavorable stack discharge conditions

8. Air flow is very complex. While many installations lend themselves to simple "rule-of-thumb" solutions, it should be re-emphasized that others will require thorough analysis, including wind tunnel and full scale smoke and dispersion tests.

It should be clear from these air flow principles that contaminant discharges should not be terminated at or near the roof level. To assure discharge away from the building and thus minimize re-entry the stack should discharge above the cavity. If minimum practical diffusion is required, the discharge must be above the contour zone. The final height should be determined by the dispersion requirements.

7.6 Economic Considerations

7.61 Introduction

Mr. Francis L. Bunyard, Economic Effects Research Division, NAPCA, Durham, North Carolina, in his work dated December 1968 and entitled "A Presentation of Cost Data for Air Pollution Control Equipment and a Technique for Calculating the Cost of Control" developed a process model for thermal and catalytic incineration equipment which has direct application to the graphic arts industry. Based on process knowledge developed during Phase I, and considering the technical and economic parameters identified, little if any additional information can be added to that of Mr. Bunyard. Therefore, the guidelines which he developed for evaluating emission control alternatives, namely catalytic and thermal incineration, will be presented in this paper.

The authors also wish to acknowledge the economic and technical parameters as presented by H. L. Barneby and W. L Davis of Barneby-Cheney Company in their paper entitled "Costs of Solvent Recovery Systems" which appeared in Chemical Engineering, December 29, 1958. Recent communication with one of the authors indicates that although costs in general have risen the method is still useful. He recommends adding 10% to the costs presented in his paper stating that some recent technological advances have offset part of the costs.

7.62 Selection of Control Systems

Figure 34 (Appendix B) shows the factors to be considered in selecting a gas cleaning system. The first consideration is the degree of reduction of emissions which may be required to meet emission standards. The degree of emission reduction or the collection efficiency required is dependent upon the relationship between emissions and emission standards as indicated at the top of the figure. This is an important factor in making the choice among control equipment alternatives. The usual ranges of collection efficiency for various equipment alternatives are:

Incineration	Efficiency Range
Catalytic	80-95%
Direct Flame	95-99^{+}%
Adsorption	95-99.9%

The next important factors to be considered are the gas stream and the characteristics of the process itself. A number of factors that relate to plant facility should also be considered, some of which are listed in Figure 34 (Appendix B). Each alternative will have a specific cost associated with it and therefore those alternatives which meet the requirements of both the process and the plant facility can then be evaluated in terms of cost. On this basis, the gas cleaning system may be selected.

7.63 Description of Control Cost Elements

The actual cost of installing and operating air pollution control equipment is a function of many direct and indirect cost factors. An analysis of the control costs for a specific source should include an evaluation of all relevant factors as outlined in Figure 34 (Appendix B). The control system must be designed and operated as an integral part of the process; this will minimize the cost of control for a given emission level. The definable control costs are those that are directly associated with the installation and operation of control systems. These expenditure items from the control equipment user's point of view have a breakdown for accounting purposes as follows (69):

A. Capital Investment
    1. Engineering studies
    2. Land
    *3. Control hardware
    *4. Auxiliary equipment
    *5. Installation
    6. Start-up
    7. Structure modification

B. Maintenance and Operation
    *1. Utilities
    *2. Labor
    *3. Supplies and materials

C. Capital Costs
   *1. Taxes
   *2. Insurance
   *3. Interest

Of the expenditure items shown above, only those denoted by an asterisk were considered in developing the cost estimates used in this section of the report. Other factors, such as engineering studies, land acquisition and structural modification, vary in cost from place to place and therefore were not included.

It should be emphasized that the control cost elements that have been outlined as part of the development of the cost estimates are based on a 1967 index and will have to be factored accordingly to meet current or more recent cost estimates.

1. Capital Investment

The "installed cost" quoted by a manufacturer of air pollution equipment usually is based on his engineering study of the actual emission source. This cost includes three of the seven capital investment items — control hardware costs, auxiliary equipment costs and costs for field installation.

The remaining capital investment items, auxiliary equipment and installation costs, are aggregated together and referred to as "total installation costs." These costs include a reasonable increment for the following items:

(a) erection
(b) insulation material
(c) transportation of equipment
(d) site preparation
(e) auxiliary equipment such as fans, ductwork, motors and control instrumentation.

For incineration and adsorption equipment, these costs are shown in Table 41 expressed as percentages of the purchase costs. The low values listed in the table are for minimal transportation and simple layout and installation of control devices. High values are for higher transportation cost and for difficult layout and installation problems.

TABLE 41

TOTAL INSTALLATION COST FOR INCINERATION AND ADSORPTION SYSTEMS AS A PERCENTAGE OF PURCHASE COSTS (69)

Equipment Type	Percent of Cost		
	Low	Typical	High
Incinerators	10	25	100
Adsorption	15	30	100

7.64 Cost Curves

Figures 35, 36, 37 (Appendix B) representing (a) purchase cost of incinerators, (b) installation cost and (c) annual operational cost of incinerators have been prepared and are presented as a guide to estimating this type of control equipment costs

The purchase cost curve depicts the dollar amounts charged by the manufacturer of equipment constructed of standard materials, exclusive of transportation charges to the installation site (69).

The installed cost curve shows the purchase cost plus the shipping or transportation cost to the point of installation, site preparation for accommodating the control equipment, installation cost including normal ductwork, insulation and fans (69).

The annual operational cost curve shows the estimated cost including annual capital charges, depreciation of installed equipment (assuming a fifteen-year expected operating life with straight line depreciation) as well as operating and maintenance charges (69).

In order to understand the cost curves and the related tables, acfm refers to actual cubic feet per minute (uncorrected for temperature and pressure) as opposed to scfm which is standard cubic feet per minute (corrected to standard conditions, 60°F and 29.92 inches of mercury).

7.65 Annualizing the Cost of Control

One approach to expressing the total cost of control is to consolidate all associated cost items and report them as a recurring annual cost of control. In order to develop this annual cost of control certain assumptions are made (69).

1. Purchase and installation costs are depreciated over 15 years; this period assumed as feasible economic life for control devices.

2. Straight line depreciation offers simplicity and is utilized in this approach as a constant annual write-off.

3. The cost of additional charges for capital such as interest, taxes, insurance, etc., are assumed to be equal to the amount of depreciation. Therefore, depreciation plus these additional charges are assumed to amount to 6-2/3 percent plus 6-2/3 percent or 13-1/3 percent of the initial capital cost of the control equipment installed.

4. Maintenance cost is the expenditure required to sustain the operation of a control device at its designed efficiency. In the case of incinerators, the annual maintenance cost factors have been developed and are presented in Table 42.

TABLE 42

ANNUAL MAINTENANCE COST FACTOR (69)

Incineration	Dollar per acfm		
	Low	Typical	High
Direct Flame	0.03	0.06	0.10
Catalytic	0.07	0.20	0.35

The more simple the control device, the lower the maintenance cost. The table depicts the range of factors used in developing the cost figures.

5. Annual operating costs is the expense of operating a control device at its designed collection efficiency. This cost depends on the following engineering factors which have been developed for incineration control equipment (69).

   A. The amount of gas volume to be cleaned.
   B. The pressure drop across the system for incinerators.

Pressure Drop Through Equipment (in H_2O)

Low	Typical	High
0.5	1.0	2.0

C. Operating time, assume continuous operation of 8760 hours per year (24 hr/day x 365 days/yr).

D. Cost of Electricity ($ per Kw-hr)

Assume:	Low	Typical	High
	0.005	0.011	0.020

E. Mechanical efficiency of fan (assumed to be 60 percent)

F. Fuel Cost (Table 43)
(Although natural gas costs can vary from $0.35 to $1.02 per million Btu, the hourly fuel costs were based on a natural gas cost of $0.60 per million Btu.)

TABLE 43

HOURLY FUEL COSTS OF INCINERATION EQUIPMENT (69)

	Hourly Fuel Costs			
Device	Temperature, °F		Temperature	*Fuel Cost
	Inlet	Outlet	Increase (ΔT)	dollars/acfm/hr
Direct flame	380	1400	1020	$0.00057
Direct flame w/heat exchanger	1000	1400	400	0.00023
Catalytic afterburner	380	900	520	0.00028
Catalytic afterburner w/heat exchanger	650	900	250	0.00014

*Includes the cost of heating an additional 50% excess air and assumes no heat value content in the material or pollutant consumed.

7.66 Equation for Calculating the Annual Operation and Maintenance Costs of Incineration Equipment

An equation has been developed (69) to determine the theoretical value for annual operating cost. The equation is as follows:

$$G = S \left[\frac{0.7457}{6356} \left(\frac{PHK}{E} \right) + HF + M \right]$$

where

G = theoretical value for operating and maintenance costs
S = design capacity of the afterburner (acfm)
P = pressure drop (in H_2O) across equipment
E = fan efficiency (assumed to be 60%)

0.7457 = a constant (1 horsepower = 0.7457 kilowatt)

H = annual operating time (max = 8750 hours)
K = power cost, (dollars per kilowatt-hour)
F = fuel cost, (dollars per acfm per hour)
M = maintenance cost, dollars per acfm

For computational purposes, this cost formula can be simplified as follows:

$$G = S \left(195.5 \times 10^{-6}\ PHK + HF + M \right)$$

7.67 Comparative Cost Figures

There has been a great deal of effort on the part of air pollution control equipment manufacturers, especially those dealing with catalytic and thermal (direct-flame) equipment, toward developing data aimed at outlining less expensive operation. In an effort to promote one type of equipment over another, comparative cost figures have been developed by equipment manufacturers and these figures have on occassion appeared in the literature.

An interesting approach is the one taken by J. E. Yocum and R. A. Duffee ("Controlling Industrial Odors") (71) in which a comparison, shown in Table 44 (Appendix C), is made of the total costs for installing and operating both catalytic and direct flame afterburners, assuming different heating values for the incoming gas stream and different levels of heat recovery.

In looking at the ratio of costs for the two methods, it is apparent that when the incoming contaminated stream has some heating value, the catalytic method has an advantage over a flame unit.

This section of the report and the table contained within are not to be construed as representative or recommended, rather the intent is to provide the material solely as information. Each system must be evaluated individually since there are far too many parameters which influence the cost from unit to unit.

7.7 Adsorption Equipment

To properly size a system, a manufacturer of solvent vapor recovery equipment should have the following information: (70)

1. type of application
2. air flow rate
3. contaminants and their concentrations
4. degree of removal required (efficiency)
5. operating conditions, such as temperature, pressure humidity
6. other types of contaminants present, such as particulate matter, polymers, high boiler additives, etc.
7. space limitations for the equipment
8. utilities available at the application site

Table 45 may be used for approximate pricing of solvent recovery systems.

TABLE 45

INSTALLED EQUIPMENT COST PER SCFM (70)

SCFM air-rate through system	Solvent concentration (GPH per 1000 SCFM)				
	0.02	1.0	2.5	5.0	10.00
1000	14.30	15.40	17.60	20.90	23.10
2000	9.90	11.00	11.00	13.75	17.60
4000	6.60	8.52	9.62	11.05	13.20
8000	5.77	6.87	7.97	9.29	11.27
15,000	4.35	4.78	5.22	7.75	9.90
30,000	3.46	3.73	4.67	7.31	9.24
100,000	2.36	2.42	3.63	6.60	8.80

The above prices are for the solvent recovery system only, including adsorbers, cycling valves and controls, charcoal beds, condenser, decanter (if needed), blower(s) and motor(s) of standard construction, interconnecting ductwork-piping and sewers.

Add for additional costs cleared level site, ductwork, piping sewers leading to and from the system and insulation of equipment. Use of explosion proof electrical equipment and wiring, corrosion resisting materials, particulate pre-filter, scrubber according to need, and distillation equipment as needed must also be added to the cost (70).

TABLE 46

OPERATING COSTS
(Basic Costs, Dollars/Gallon) (70)

	Relative Cost of Operation		
	Low	Average	High
Solvent immiscible in water (decantation)	$0.016	0.027	0.044
Water-miscible solvent (simple distillation)	0.038	0.066	0.088
Mixed solvent (complex distillation)	0.055	0.088	0.110

The Operating Costs Table 46 lists recovery costs for typical solvents of the water-immiscible type (toluene or gasoline), of the water-miscible type (alcohol or acetone) and of solvents that cannot be separated by simple distillation (a mixture of naphtha, methyl ketone and isopropanol). The recovery cost will also vary with the overall recovery efficiencies, the size of the installation and the chemical characteristics of the solvent. Therefore, low, average, and high costs are given (70).

The figures in this table represent only the direct costs, including labor, steam, water and power costs. The costs do not include such items as overhead, depreciation of the equipment or taxes (70).

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APPENDIX A

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APPENDIX A

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APPENDIX B

Figures

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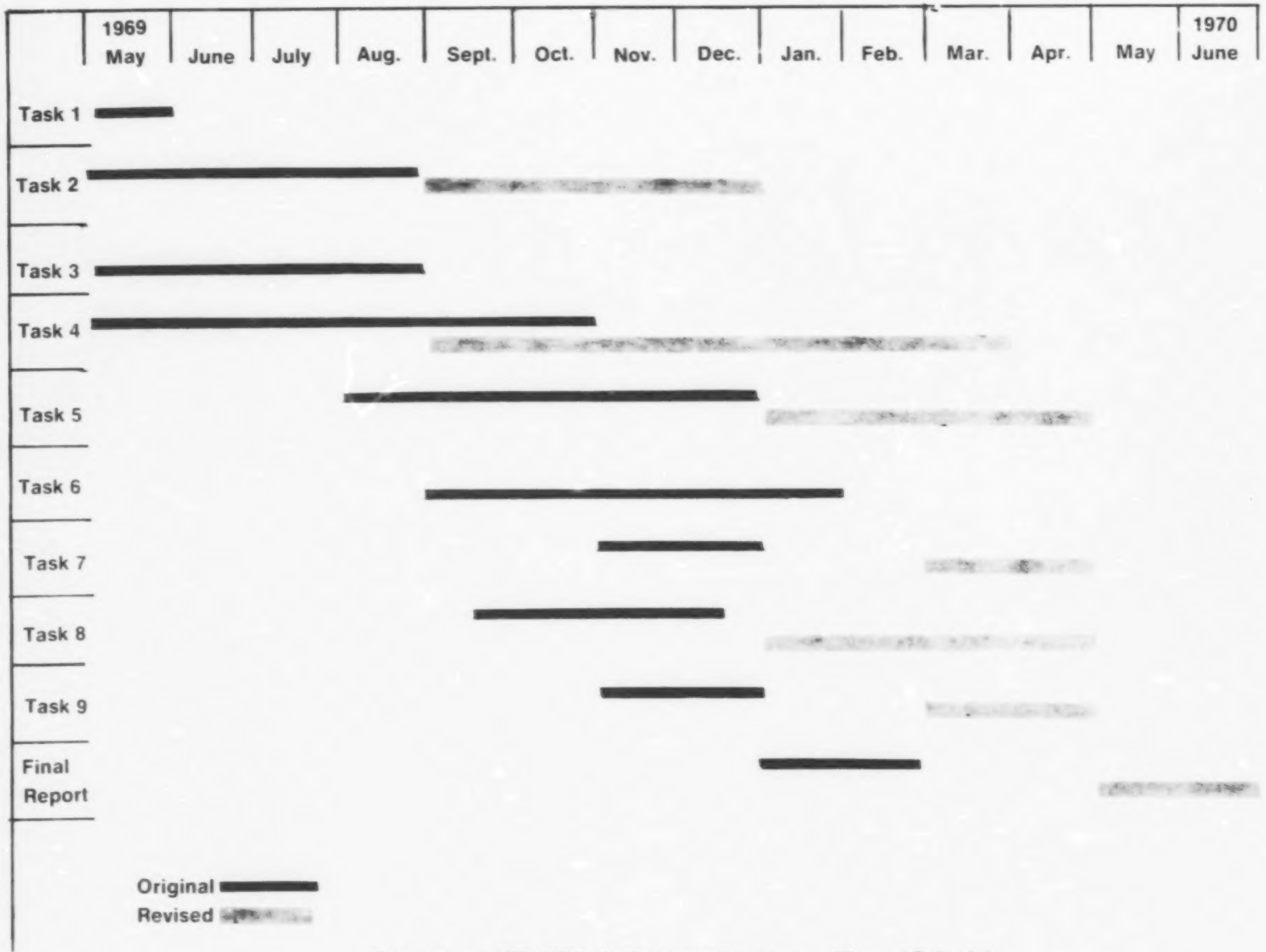


Figure 1—*GATF-HEW Air Pollution Program — Phase I Schedule.*

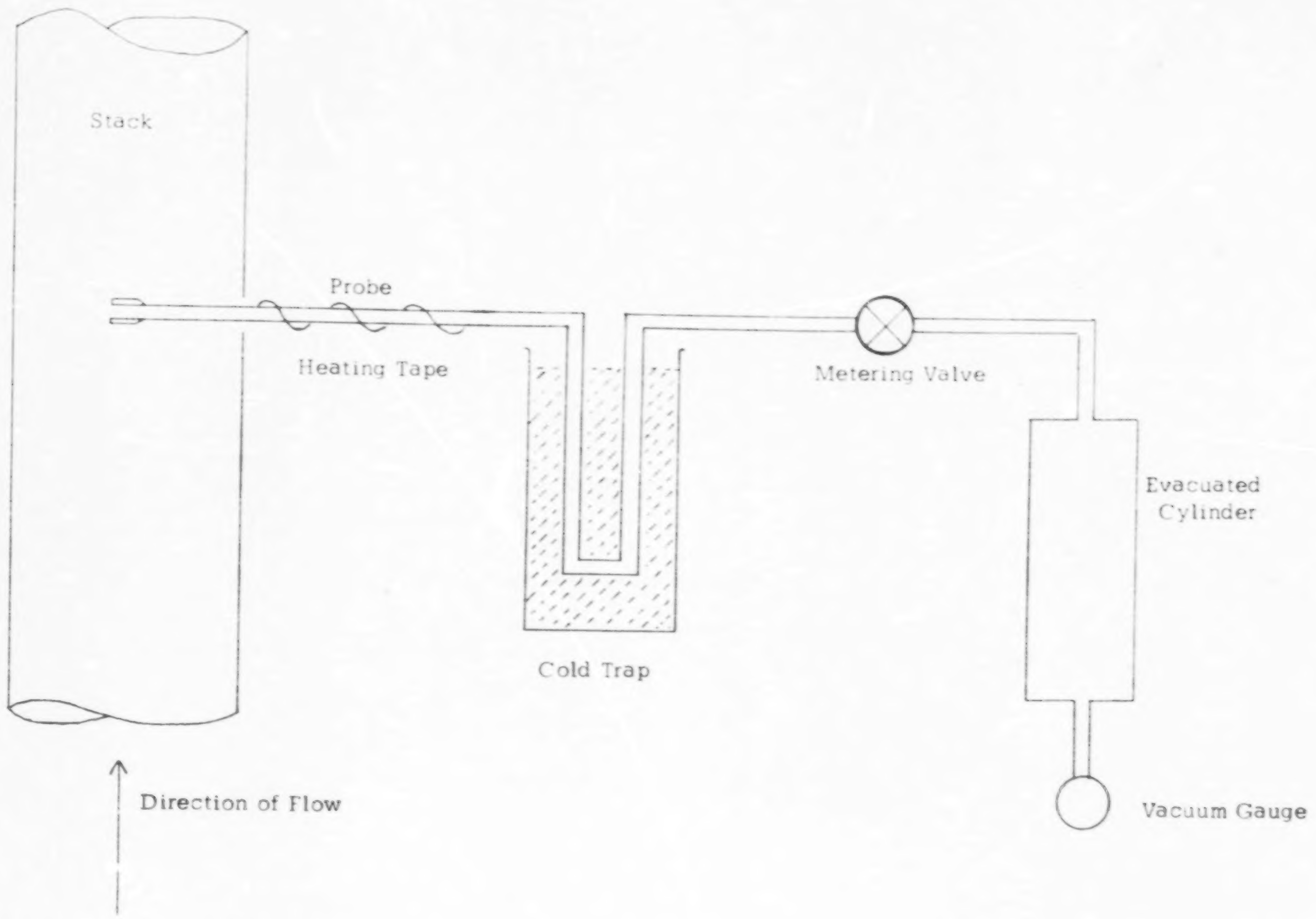

Stack
Probe
Heating Tape
Cold Trap
Metering Valve
Evacuated Cylinder
Vacuum Gauge
Direction of Flow

Figure 2

Grab Sample Train Using Evacuated Container Technique
Principle of Collection (34)

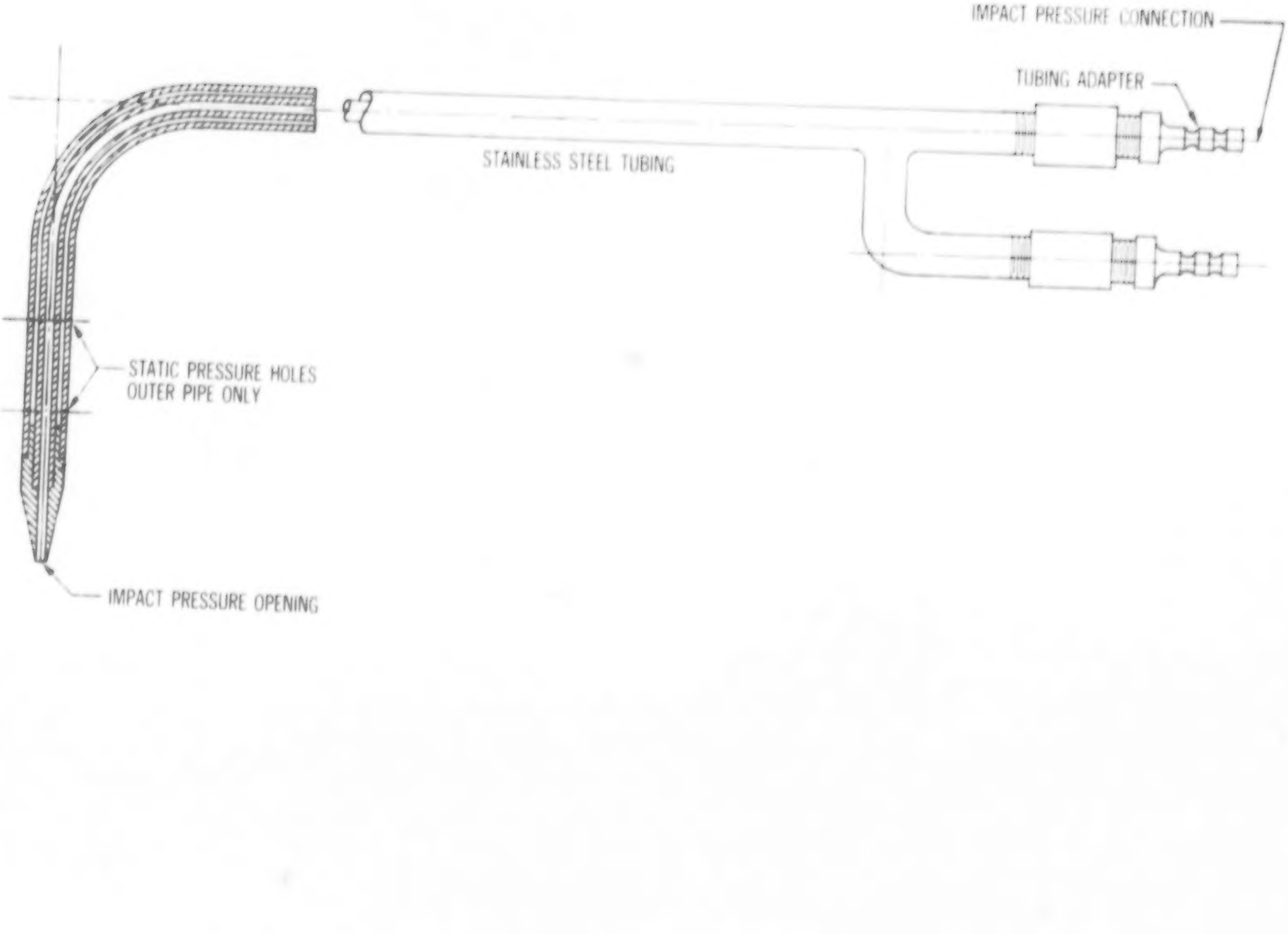

IMPACT PRESSURE CONNECTION
TUBING ADAPTER
STAINLESS STEEL TUBING
STATIC PRESSURE HOLES
OUTER PIPE ONLY
IMPACT PRESSURE OPENING

Figure 3

Standard Pitot Tube Details (37)

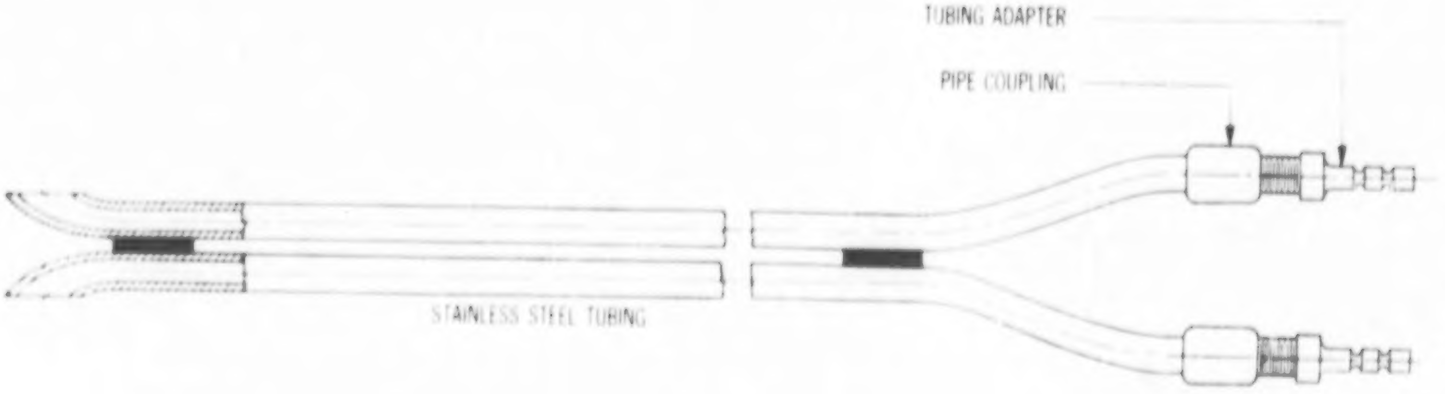

TUBING ADAPTER
PIPE COUPLING
STAINLESS STEEL TUBING

Figure 4

Type S Pitot Tube (Special) (37).

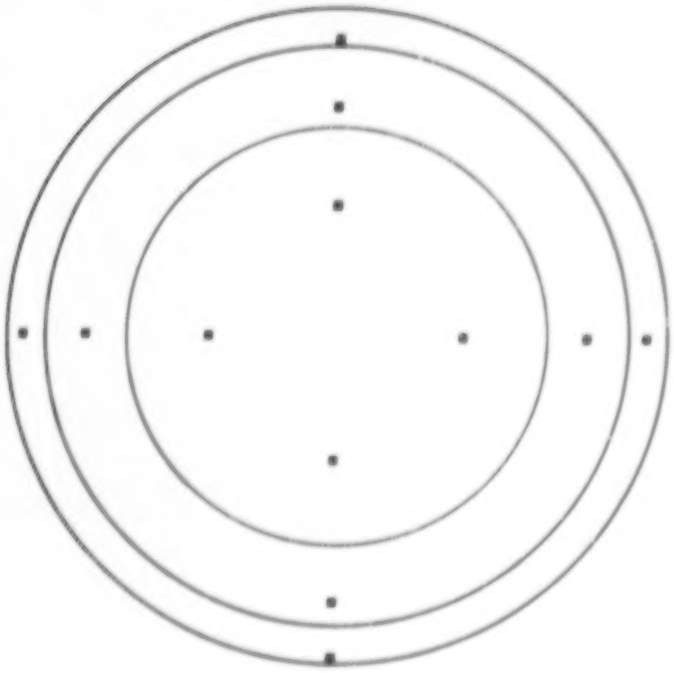


Figure 5. Cross section of a circular stack divided into three concentric equal areas, showing location of traverse points. The location and number of such points for a stack of given diameter can be determined by referring to Table 22 and Table 24 (35).

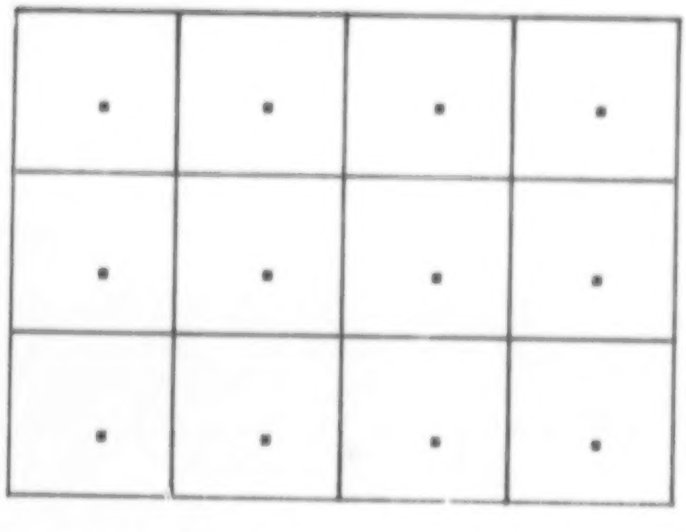


Figure 6. Cross section of rectangular stack divided into 12 equal areas, with traverse points located at the center of each area. Number of equal areas for velocity measurement is shown in Table 23 (35).

CAL-COLONIAL CHEMSOLVE
CHROMATOGRAPHIC
FLAME IONIZATION ANALYSIS

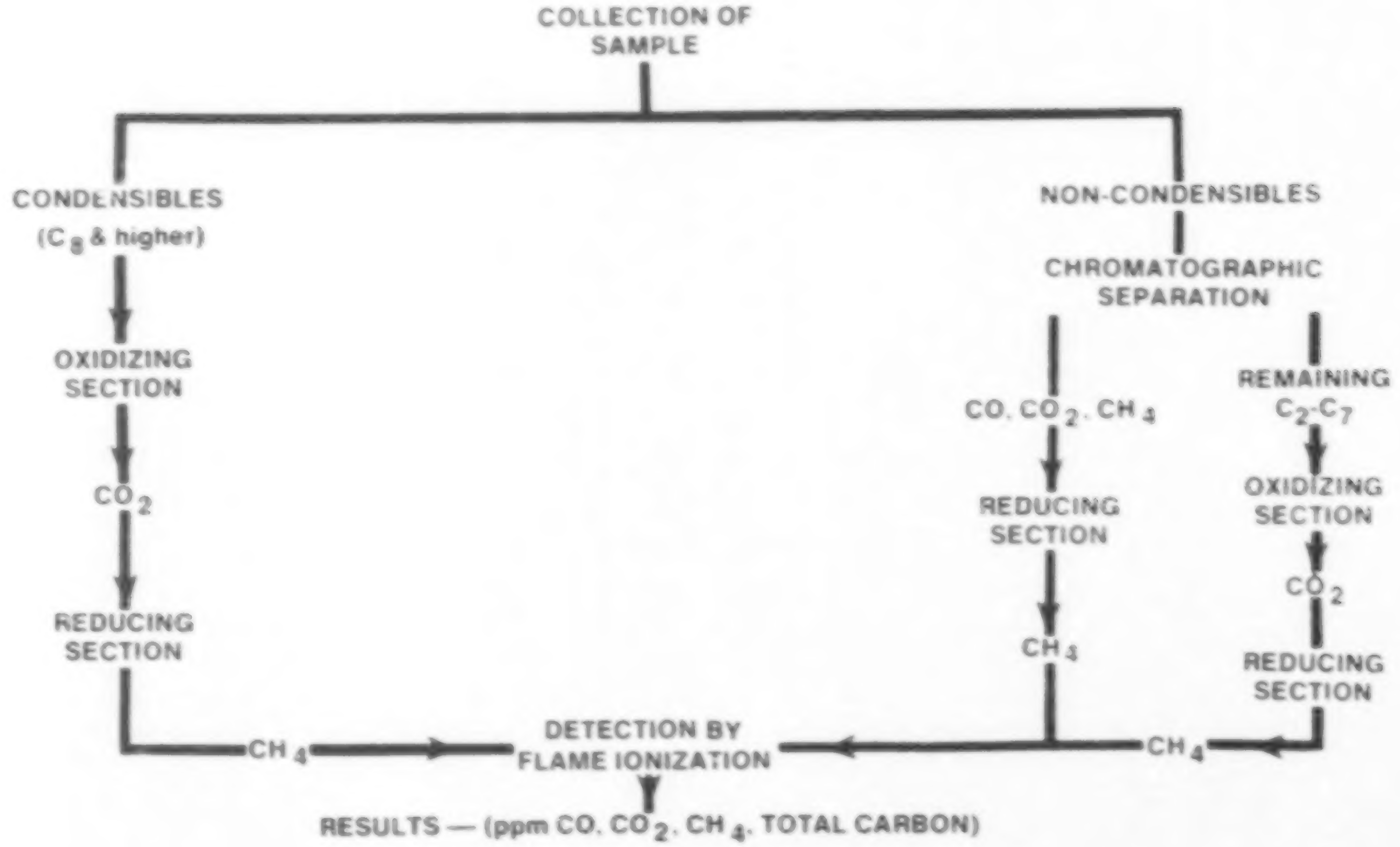

COLLECTION OF SAMPLE
CONDENSIBLES
(C_8 & higher)
OXIDIZING SECTION
CO_2
REDUCING SECTION
CH_4
NON-CONDENSIBLES
CHROMATOGRAPHIC SEPARATION
CO, CO_2, CH_4
REDUCING SECTION
CH_4
REMAINING
C_2-C_7
OXIDIZING SECTION
CO_2
REDUCING SECTION
CH_4
DETECTION BY FLAME IONIZATION
RESULTS — (ppm CO, CO_2, CH_4, TOTAL CARBON)

Figure 7

LOS ANGELES A.P.C.D.

CHROMATOGRAPHY — COMBUSTION — INFRARED ANALYSIS

(TOTAL COMBUSTION ANALYSIS)

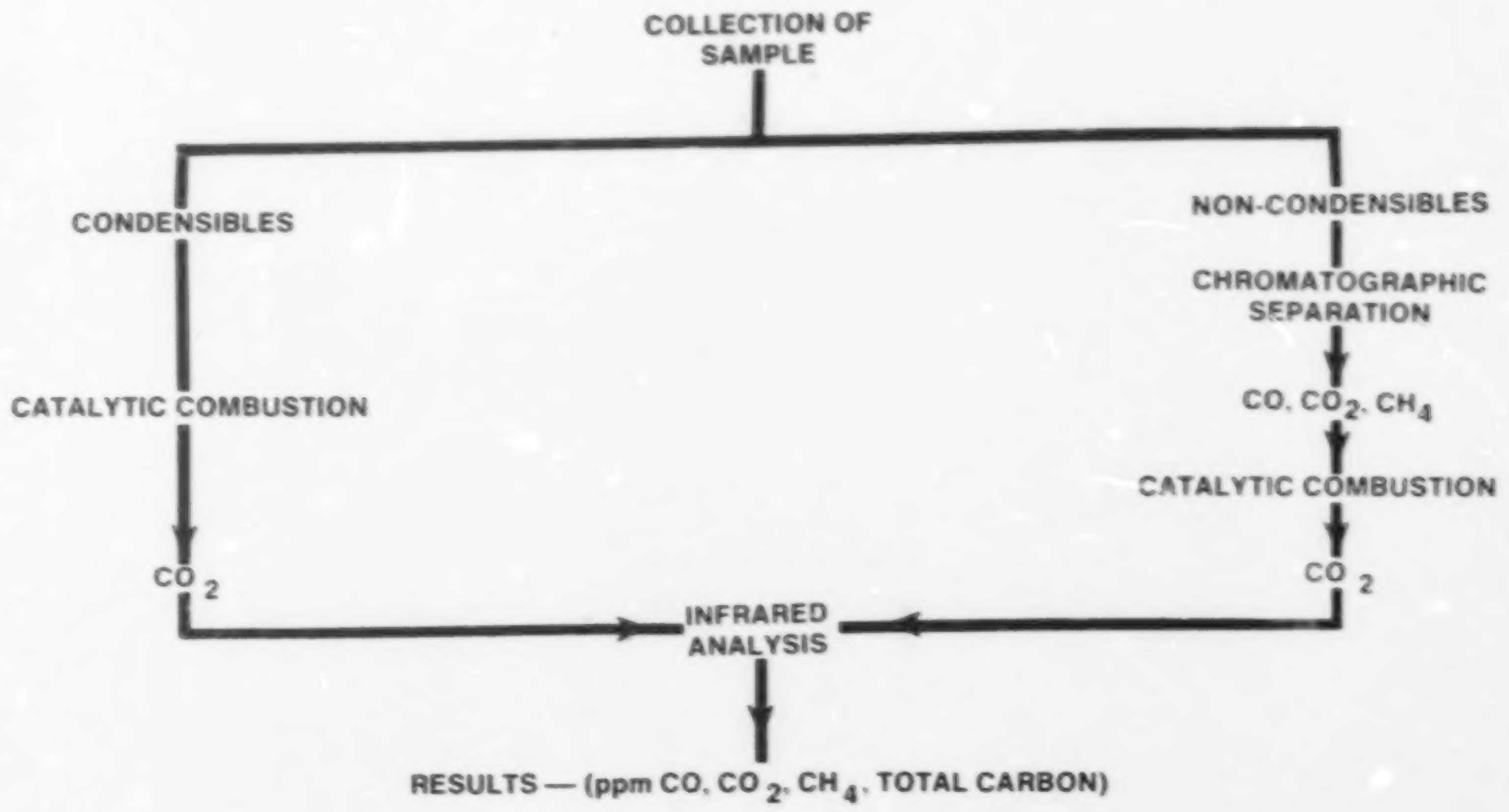

COLLECTION OF SAMPLE
CONDENSIBLES
CATALYTIC COMBUSTION
CO_2
NON-CONDENSIBLES
CHROMATOGRAPHIC SEPARATION
CO, CO_2, CH_4
CATALYTIC COMBUSTION
CO_2
INFRARED ANALYSIS
RESULTS — (ppm CO, CO_2, CH_4, TOTAL CARBON)

Figure 8

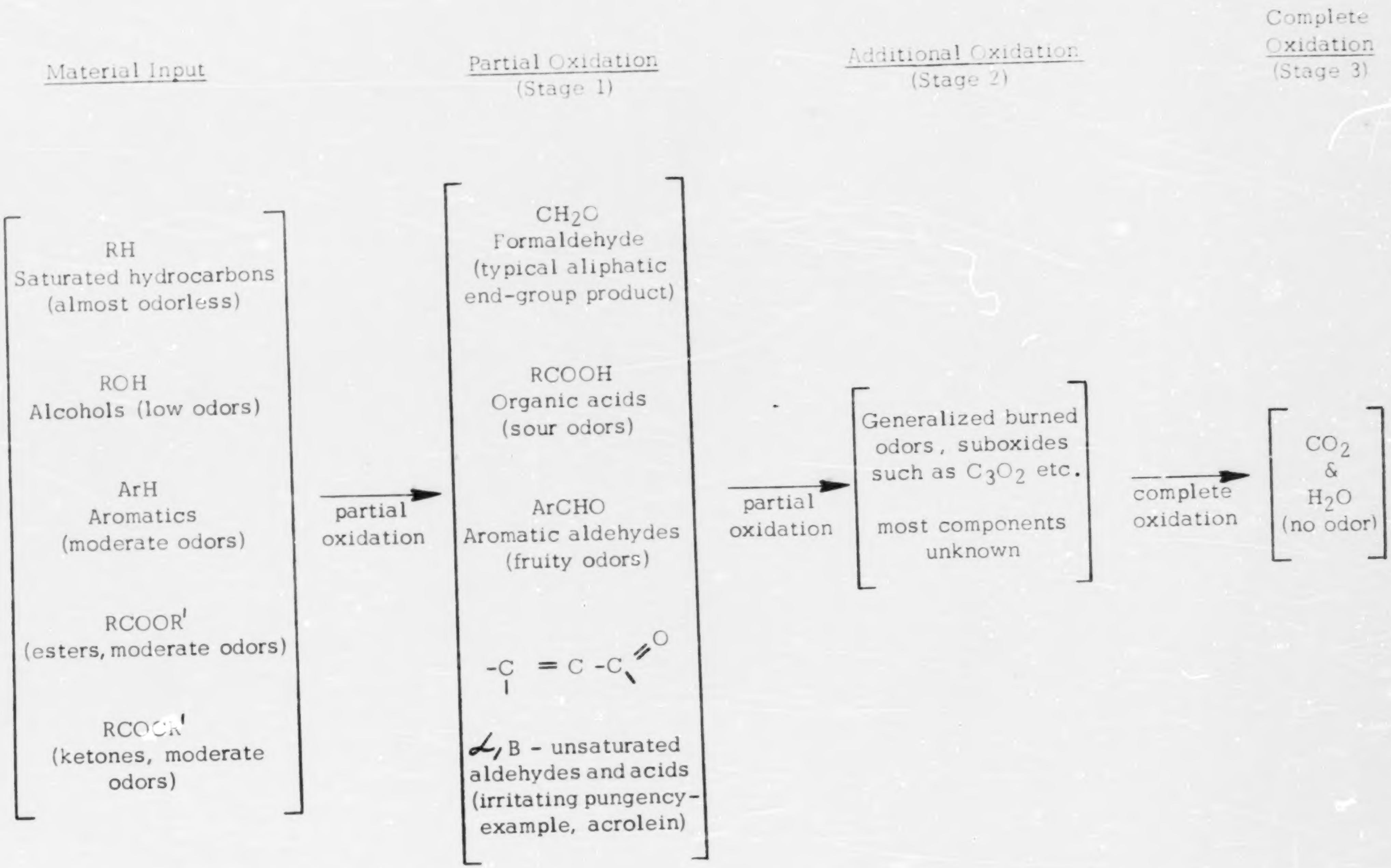

Material Input
Partial Oxidation
(Stage 1)
Additional Oxidation
(Stage 2)
Complete
Oxidation
(Stage 3)
RH
Saturated hydrocarbons
(almost odorless)
ROH
Alcohols (low odors)
ArH
Aromatics
(moderate odors)
RCOOR'
(esters, moderate odors)
RCOOR'
(ketones, moderate odors)
partial oxidation
CH$_2$O
Formaldehyde
(typical aliphatic end-group product)
RCOOH
Organic acids
(sour odors)
ArCHO
Aromatic aldehydes
(fruity odors)
-C = C -C=O
α, B - unsaturated aldehydes and acids (irritating pungency- example, acrolein)
partial oxidation
Generalized burned odors, suboxides such as C$_3$O$_2$ etc.
most components unknown
complete oxidation
CO$_2$
&
H$_2$O
(no odor)

Figure 29

Products Produced at Various Oxidation Stages During Incineration (60)

Thermal Incineration

An air pollution control device whereby a contaminant laden gas stream is passed over a burner flame or other suitable preheat device to a residence chamber where the contaminant materials are oxidized to predominantly carbon dioxide and water vapor. Combustible concentration must be below the lower explosive limit (L.E.L.). Efficiencies expected from 90 - 99%.

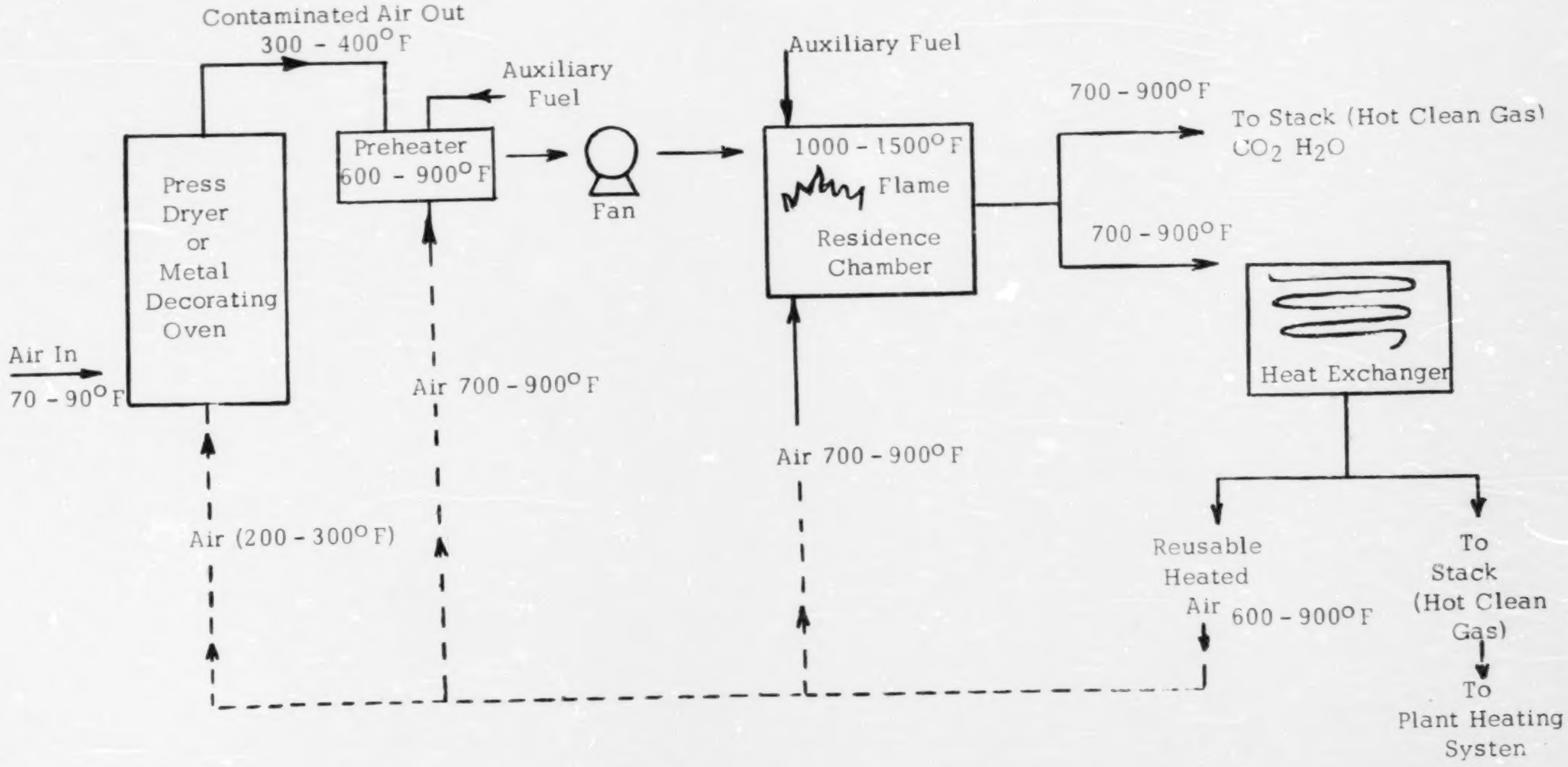

Contaminated Air Out
300 - 400° F
Air In
70 - 90° F
Press Dryer or Metal Decorating Oven
Preheater
600 - 900° F
Auxiliary Fuel
Fan
Auxiliary Fuel
1000 - 1500° F
Flame
Residence Chamber
700 - 900° F
To Stack (Hot Clean Gas)
CO_2 H_2O
700 - 900° F
Heat Exchanger
Air 700 - 900° F
Air (200 - 300° F)
Air 700 - 900° F
Reusable Heated Air
600 - 900° F
To Stack (Hot Clean Gas)
To Plant Heating Systen

Figure 30

Flow Diagram Indicating Direction of Air Flow
Including Possibilities for Heat Recovery

Catalytic Incineration

An air pollution control device whereby a contaminant laden gas stream is preheated by a heating mechanism and then passed through a catalyst bed where the contaminants are oxidized to predominantly carbon dioxide and water vapor. Combustible concentration must be below the lower explosive limit (L.E.L.). Efficiencies expected from 80 - 95%.

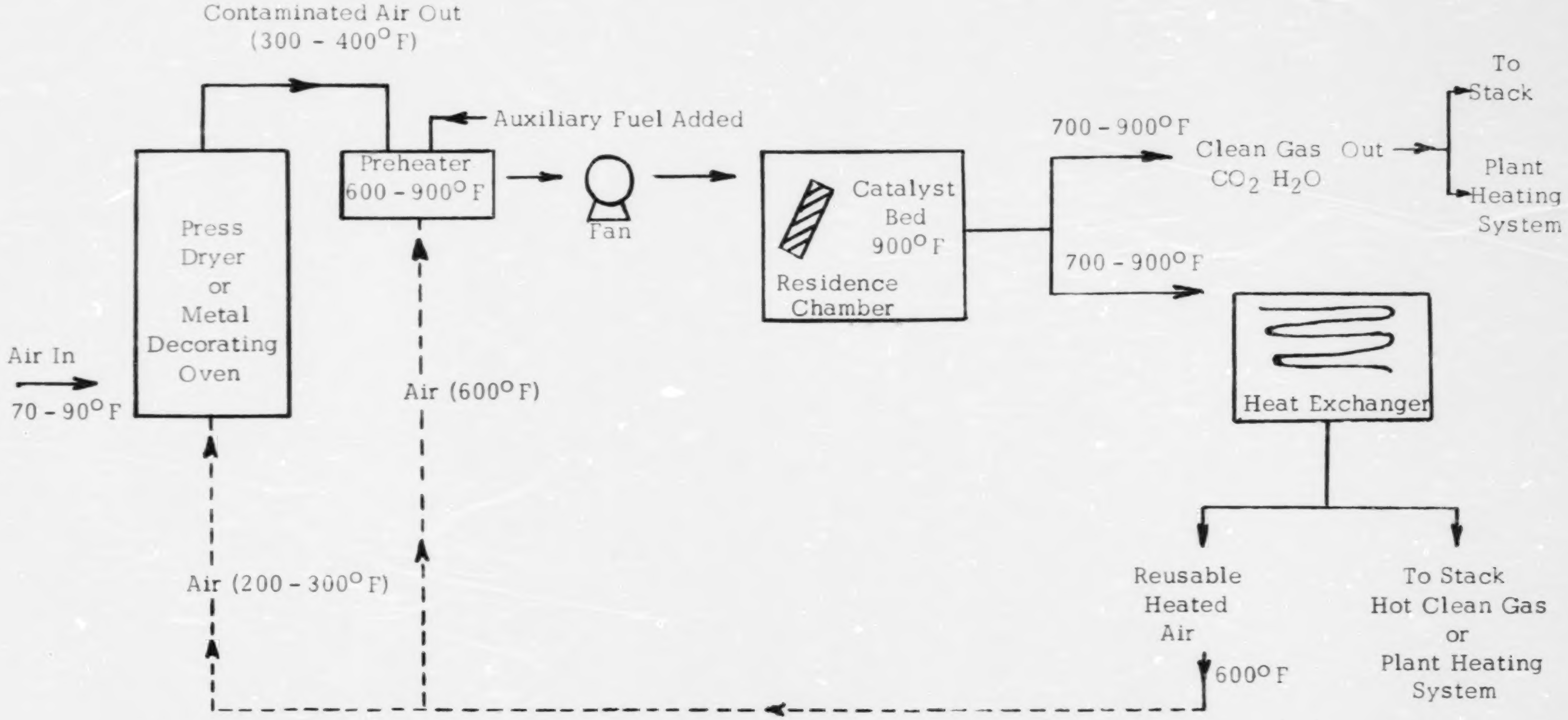

Contaminated Air Out
(300 - 400° F)
Auxiliary Fuel Added
Air In
70 - 90° F
Press Dryer or Metal Decorating Oven
Preheater 600 - 900° F
Fan
Catalyst Bed 900° F
Residence Chamber
700 - 900° F
Clean Gas Out
CO_2 H_2O
To Stack
Plant Heating System
700 - 900° F
Heat Exchanger
Air (600° F)
Air (200 - 300° F)
Reusable Heated Air
600° F
To Stack Hot Clean Gas or Plant Heating System

Figure 31

Flow Diagram Indicating Direction of Air Flow Including Possibilities for Heat Recovery

ADSORPTION (Solvent-Recovery System)

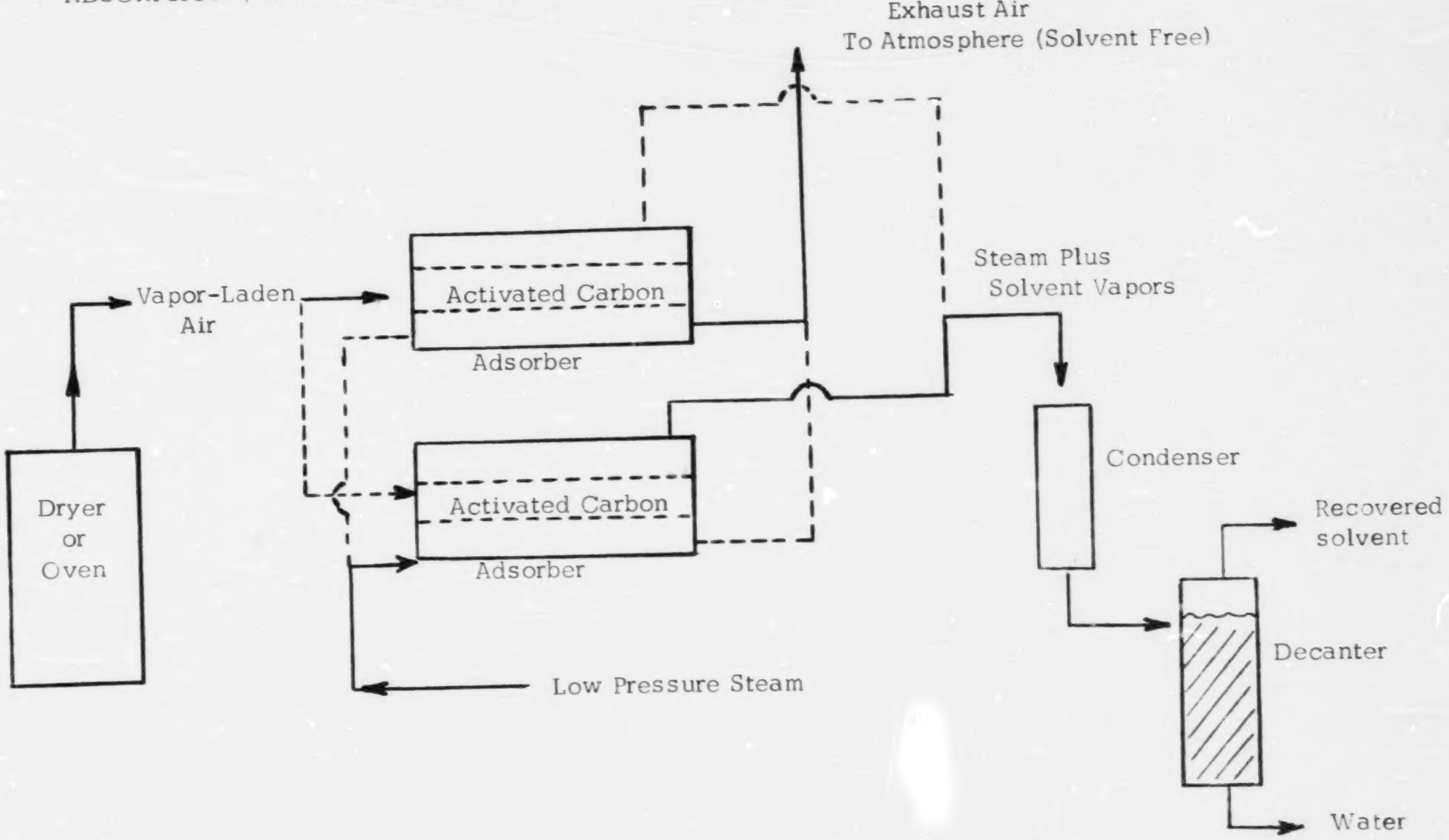

Exhaust Air
To Atmosphere (Solvent Free)
Steam Plus
Solvent Vapors
Vapor-Laden
Air
Activated Carbon
Adsorber
Activated Carbon
Adsorber
Dryer
or
Oven
Condenser
Recovered
solvent
Decanter
Water
Low Pressure Steam

Figure 32

Flow Diagram of Adsorption Process
Switching of air flows would be necessary to achieve adsorption-regeneration cycle (63).

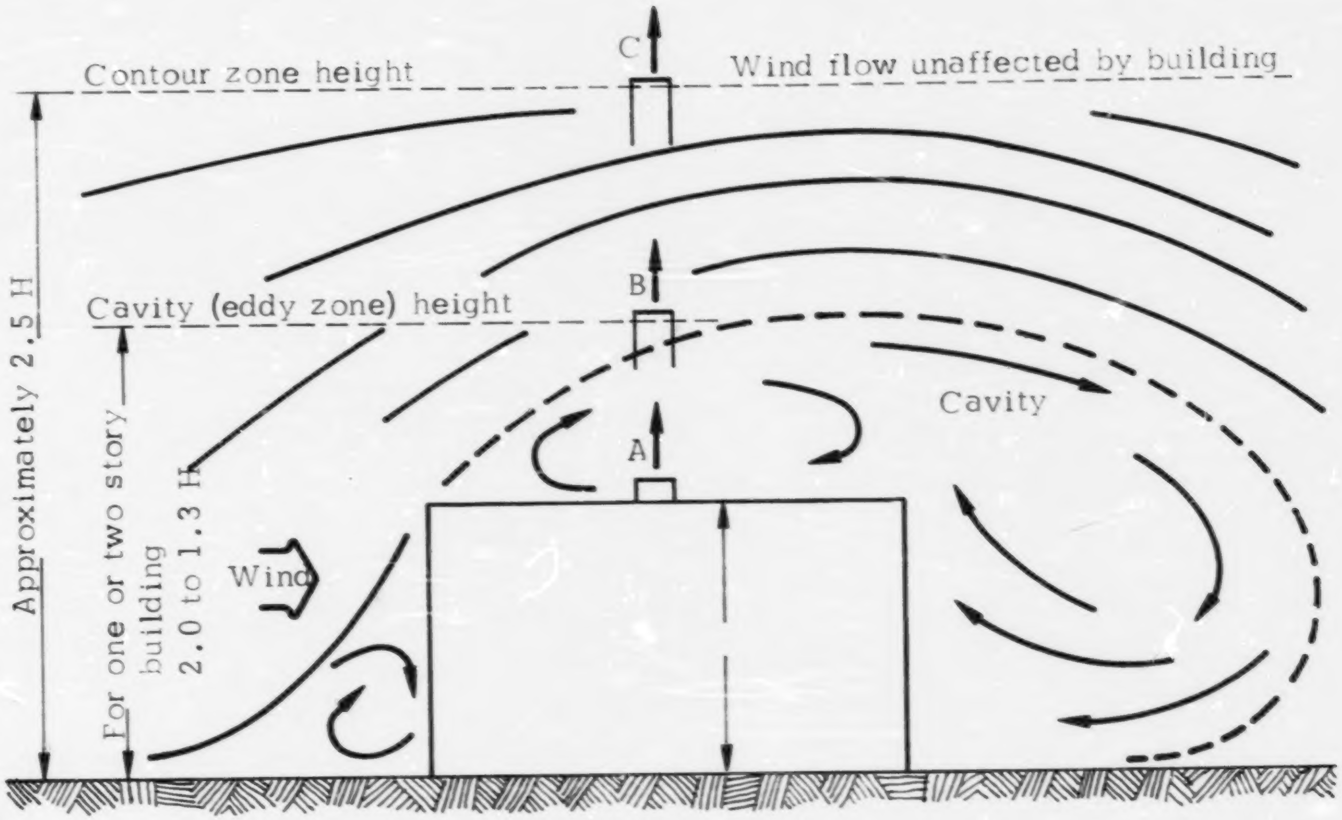

C
Contour zone height
Wind flow unaffected by building
B
Cavity (eddy zone) height
Approximately 2.5 H
For one or two story building 2.0 to 1.3 H
A
Cavity
Wind

Figure 33

Discharge of Contaminants at Various Stack Heights (68)

A. Poor discharge, re-entry of effluent most probable.
B. Discharge is satisfactory, re-entry will be avoided, however, dispersion may be marginal or poor resulting in excessive build-up in nearby area.
C. Discharge in this area is good, no re-entry and maximum dispersion.

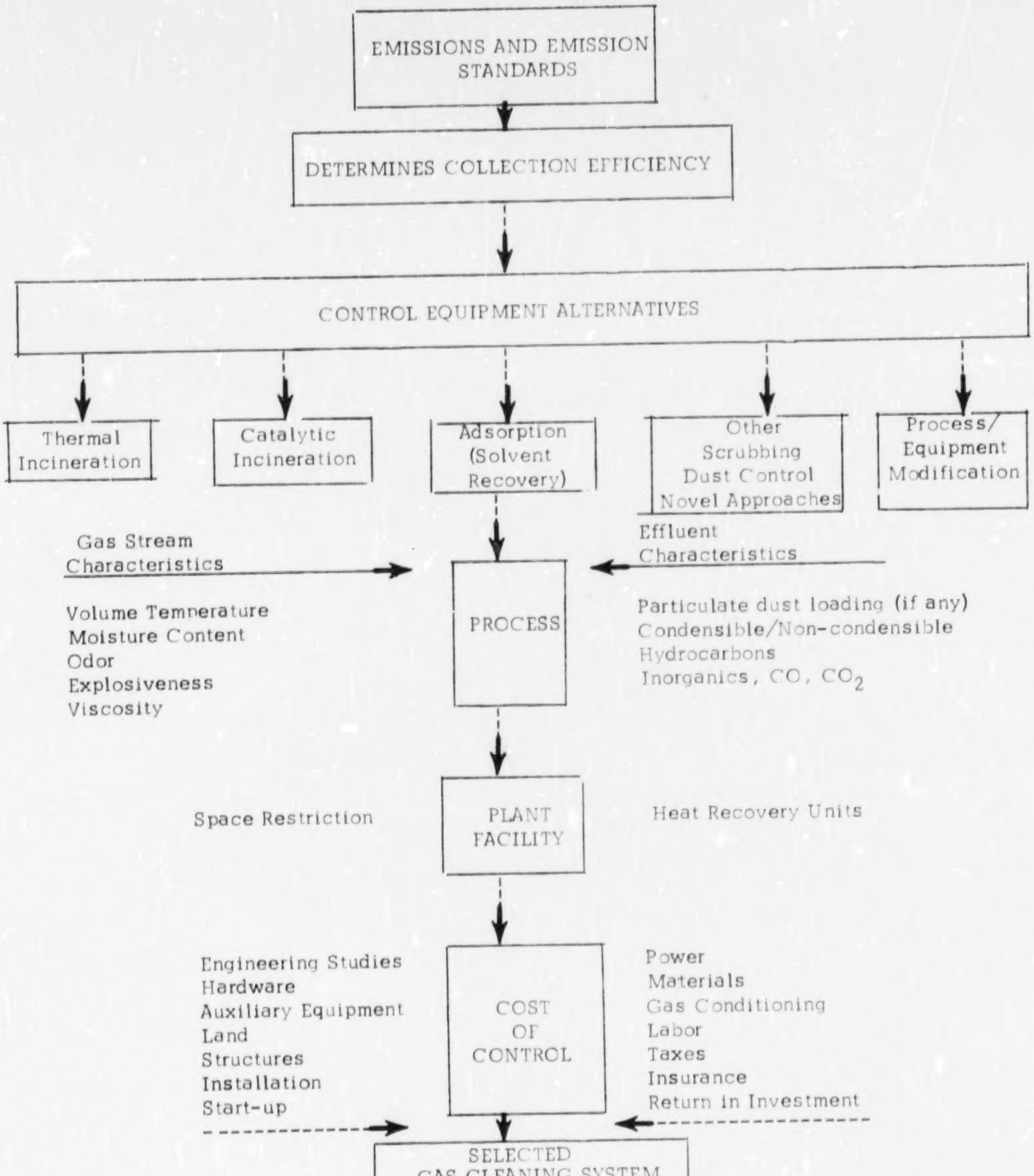
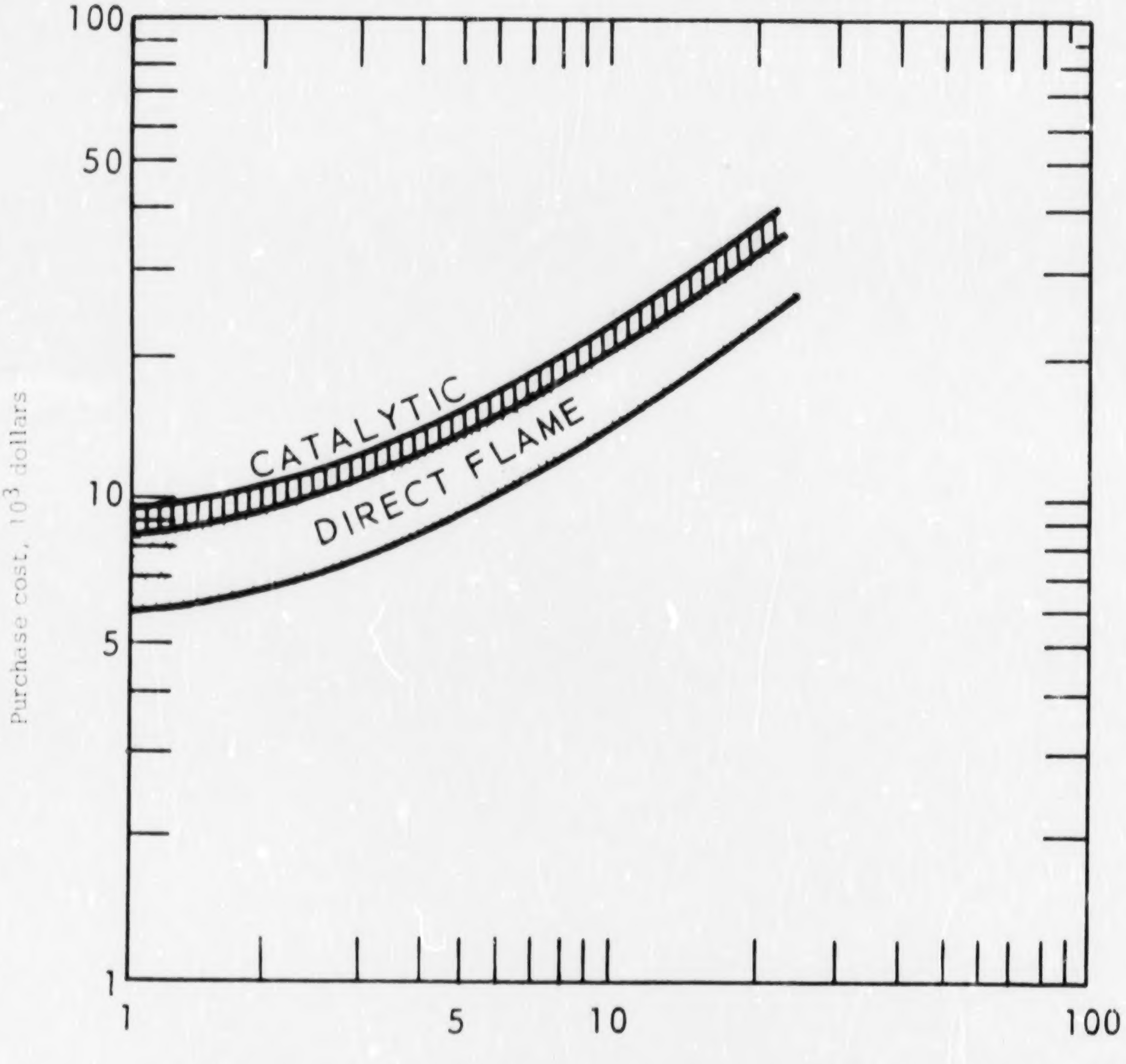

EMISSIONS AND EMISSION STANDARDS
DETERMINES COLLECTION EFFICIENCY
CONTROL EQUIPMENT ALTERNATIVES
Thermal Incineration
Catalytic Incineration
Adsorption (Solvent Recovery)
Other Scrubbing Dust Control Novel Approaches
Process/ Equipment Modification
Gas Stream Characteristics
Volume Temperature
Moisture Content
Odor
Explosiveness
Viscosity
PROCESS
Effluent Characteristics
Particulate dust loading (if any)
Condensible/Non-condensible
Hydrocarbons
Inorganics, CO, CO2
Space Restriction
PLANT FACILITY
Heat Recovery Units
Engineering Studies
Hardware
Auxiliary Equipment
Land
Structures
Installation
Start-up
COST OF CONTROL
Power
Materials
Gas Conditioning
Labor
Taxes
Insurance
Return in Investment
SELECTED GAS CLEANING SYSTEM
Desired Emission Rate

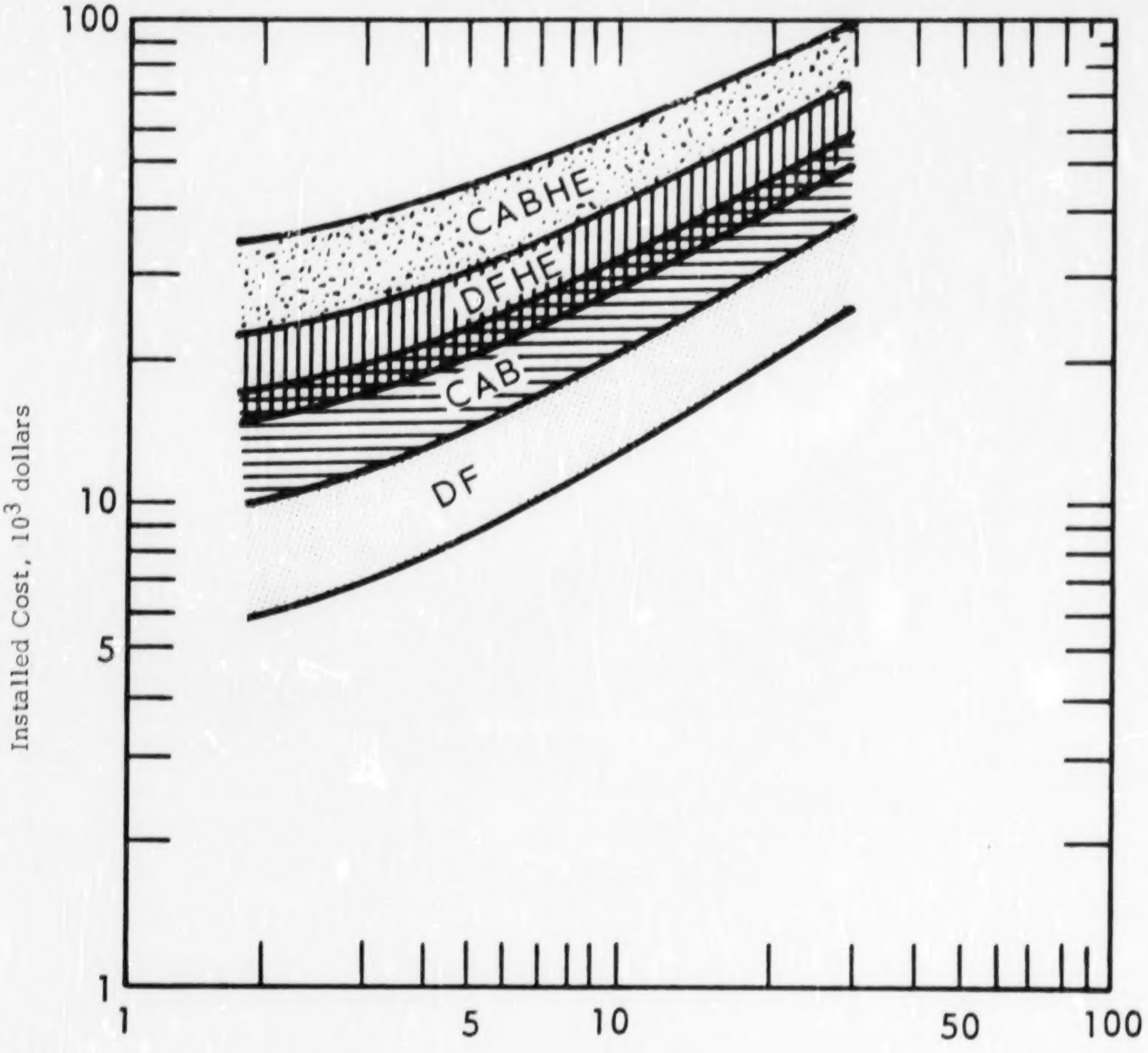
Figure 34
Factors to be Considered of Gas Cleaning System (69)



Gas Volume Through Collector, 10^3 acfm

Figure 35

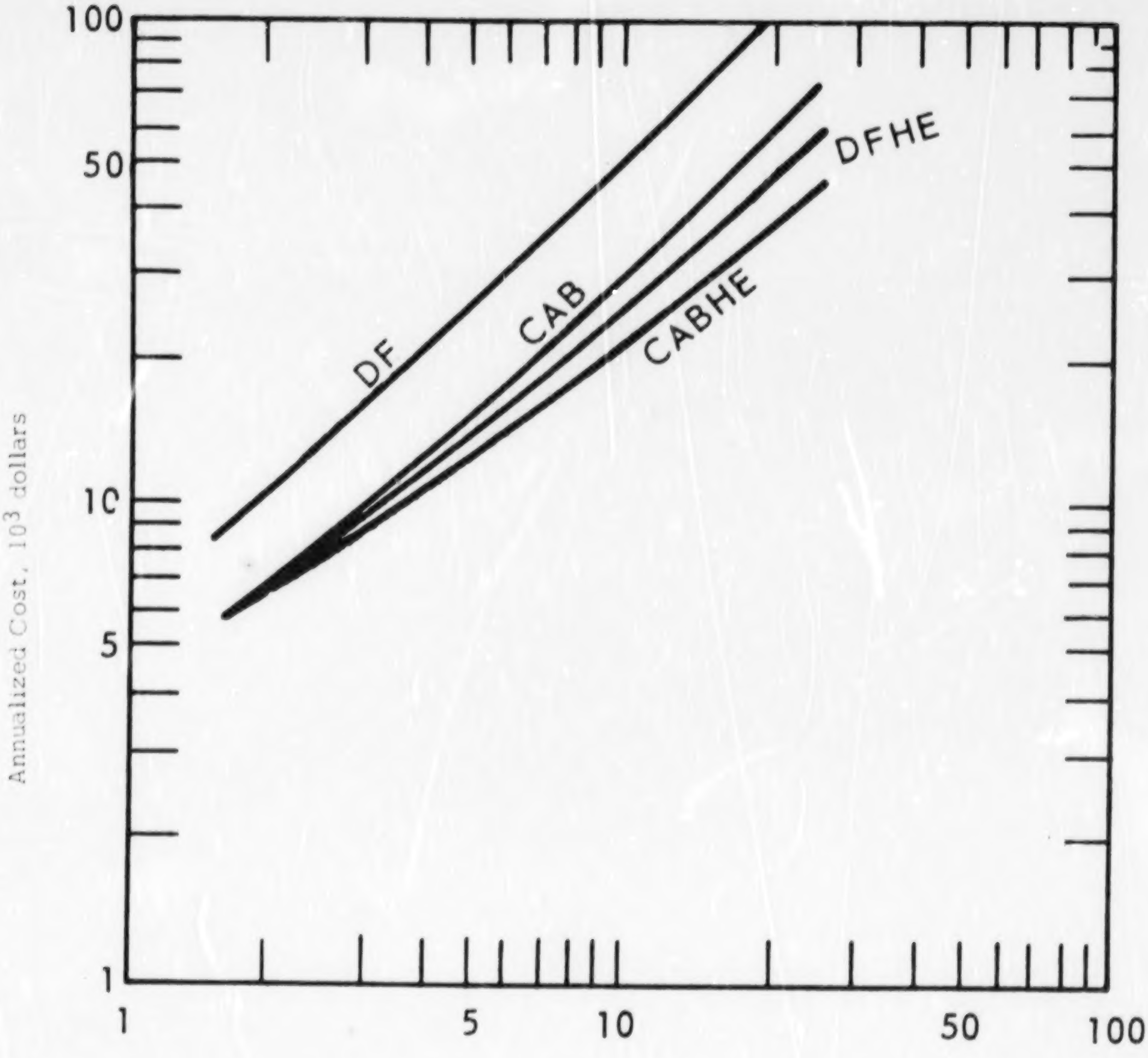
Purchase Cost of Incinerators (69)



Gas Volume Through Collector, 10^3 acfm

Figure 36

Installed Cost of Incinerators (69)



Gas Volume Through Collector, 10^3 acfm

Figure 37

Annualized Cost of Operation for Incinerators (69)

APPENDIX C

Tables

TABLE 1

GEOGRAPHICAL DISTRIBUTION OF THE COMMERCIAL PRINTING MARKET
(By SIC)

Geographic Area	Value of Shipments 1967[a] ($ million)					
	2751 (inclusive)	27510 (Lp.)	275178 (Cr.)	27512 (Fl.)	27519 (Sc.)	2752 (Litho)
New England	207.4	y[b]				189.4
Middle Atlantic	903.8	x[b]	>2/3 of		y	836.0
E.N. Central	1033.2	x	employees[c]	x	y	936.1
W.N. Central	162.9	y				303.7
S. Atlantic	331.3	y	y		y	274.0
E.S. Central	139.3					109.8
W.S. Central	125.2		y	x		108.8
Mountain	41.8					48.1
Pacific	294.1	y	y	x	y	314.5
Totals	3238.9	2236[d]	407[e]	304[e]	130[e]	3120.2

New England: Me., N.H., Vt., Mass., R.I., Conn.
Middle Atlantic: N.Y., N.J., Pa., W.Va.
E.N. Central: Ohio, Ind., Ill., Mich., Wis.
W.N. Central: Minn., Idaho, Mo., N.D., S.D., Nebr., Kans.
S. Atlantic: Md., D.C., N.C., S.C., Fla., Ga., Va., Del.
E.S. Central: Ky., Ala., Tenn., Miss.
W.S. Central: La., Ark., Texas, Okla.
Mountain: Colo., Ariz., Nev., Utah, Mont., N. Mex.
Pacific: Wash., Ore., Calif., Hawaii, Alaska

(States underlined are not included in the Area totals in one or both of the Census lists.)

Footnotes on the following page.

Table 1 cont'd.

Table 1 Footnotes

a. Except where noted otherwise, statistics are from 1967 Census Preliminary Reports (MC67(P)-27B-1 and MC67(P)-27B-2).
b. "x" indicates highest concentration areas; "y" indicates areas with large cities of high concentrations.
c. Drury, Harold F. "Gravure Growth," Gravure Technical Association Bulletin, Vol. 17, No. 2, June 1966, p. 9-10. Proportionate share of value also possible. See also Section 1.13.
d. Drury, Harold F. "Total Product Shipments...1970," Inland Printer/American Lithographer, Vol. 164, No. 4, Jan. 1970, p. 46-48. Does not include newspapers or books.
e. ibid. Industry claims figures are incomplete. (See Section 1.13).

TABLE 2

GROWTH OF COMMERCIAL PRINTING[a]

SIC	Process	Value of Receipts ($ Million) (1963)	(1967[b])	(1970[c])	Annual Rate, % (1963-67)	% Increase (1970/67[c])
27510	Letterpress	2074	2236	2814	1.9	25.8
2752	Lithography	1896	2787	4032	10.1	44.7
275178	Gravure	287	407[d]	525	9.1	30.0
27512	Flexography	263	304[e]	337	3.7	10.9
27519	Screen	69	130	210	17.1	61.5
	Total	4589	5864	7918		

a. Department of Commerce/BDSA data. (See Table 1, footnote (d) for reference.) Printing activity only. Income from other products excluded here.

b. BDSA estimates for four processes in SIC 2751.

c. BDSA projections.

d. Industry survey: 1528 (1965) and 2193 (1968). (Anon. "Survey of Gravure Printing," Gravure Technical Association Bulletin, Vol. 20, No. 2, Summer 1969, p. 10-24.) See also Section 1.13.

e. See Table 1, footnote (e).

TABLE 14

FIELD VISITS COMPLETED BY GEOGRAPHICAL AREA

	AREA VISITED					
	Pa., Ohio	Illinois, Wisconsin	N.Y., N.J., Connecticut	California	Ga., Tenn. Florida	Total
1. Printer	4	12	6	16	6	44
2. Metal Decorator	2	1	3	3	-	9
3. Ink Supplier	-	1	4	2	-	7
4. Solvent Supplier	1	1	-	-	-	2
5. Dryer Manufacturer	-	3	-	-	-	3
6. APC Equip. Mfgr.	4	-	2	1	-	7
7. Consulting Lab.	1	2	-	2	-	5
8. Engineering Lab.	1	-	-	-	-	1
9. Educational Inst.	-	1	-	-	-	1
10. APC Agency	-	1	-	2	-	4
11. Other	-	1*	1*	1**	-	3
Total	13	23	17	27	6	86

*Local Printing Association Representative
**Local HEW Field Office

KEY TO ABBREVIATIONS APPEARING IN TABLES 15 to 19

a.	G	Rotogravure
	LP	Letterpress
	L	Lithography
	F	Flexography
	MD	Metal Decorating
b.	f/m	feet per minute
	s/m	sheets per minute
	iph	impressions per hour
	s/h	sheets per hour
c.	h.a.s.h.	hot air steam heated
	h.v.h.a.	high velocity hot air
	h.a.d.f.	hot air and direct flame
	h.a.o.	hot air ovens
	o.f.	open flame
	h.a.	hot air
	s.d.	steam drum
	r.c.h.a.	radiant cup hot air
d.	d.	difficult
	a.	acceptable
	g.	good
e.	c.c.	catalytic combustion
	d.f.	direct flame afterburner
	s.r.	solvent recovery
	c.c.p.h.r.	catalytic combusion partial heat recovery
	d.f.h.r.	direct flame heat recovery
	d.u.	deodorizer unit
	s.ch.	spray chamber

n.a. Indicates that information was not available.

A number appearing before control equipment indicates number of control units.

TABLE 15

FIELD VISIT DATA

Pennsylvania and Ohio

PROCESS/EQUIPMENT			MATERIALS CONSUMED		DRYING EQUIPMENT			STACK GEOMETRY		APC EQUIPMENT[d]
Code[a]	Plate Cyl's.	Printing Speed	Ink lb/mo	Paper ton/mo	Type[c]	No.	Air Flow/°F Per Press Unit	Single/ Mnfld.	Suitable[e] Sampling	
1-G	66 20	1200 f/m 1500 f/m	75000	300000	h.a.s.h. h.a.s.h	11 5	1500 cfm/80-150 3000 cfm/80-150	M	d	s.r.
1-LP	64	1200-1600 f/m	Temporarily not Operating		h.v.h.a.	1	11000 cfm/450-500	M	d	
1-L	20	600-800 f/m			h.a.d.f.	1	3500 cfm/650-725	M	d	c.c.p.h.r.
1-MD	10*	80 s/m	n.a.	n.a.	h.a.o.	1	4-5000 cfm/372	S	a	none
2-MD	9**	80 s/m	n.a.	n.a.	h.a.o.	5	n.a./370	S	a	c.c.
2-L	8	500-800 f/m	2000	500 est.	o.f.	1	n.a./450-500	S	a	none
	12	800 f/m			h.a.	1	n.a./450-500	S	d	none
10-L	40	1200-1500 f/m	24000	n.a.	h.a.d.f.	3	3830 cfm/445	S	a	none
					h.a.	2	4000 cfm/340	S	a	none

* 6 coaters
** 5 coaters

TABLE 16

FIELD VISIT DATA

New York - New Jersey - Connecticut

PROCESS/EQUIPMENT			MATERIALS CONSUMED		DRYING EQUIPMENT			STACK GEOMETRY		APC EQUIPMENT[d]
Code[a]	Plate Cyl's.	Printing Speed[b]	Ink lb/mo	Paper ton/mo	Type[c]	No.	Air Flow/°F Per Press Unit	Single/ Mnfld.	Suitable Sampling[e]	
8-C	66	21000 iph	17000 est.	n.a.	h.a.s.h.	66	1500 cfm/95-120	S	d	none
10-MD	16*	700 s/m	35000 est.	n.a.	h.a.o.	9	3600 cfm/350	S	a	none
28-L	18	900 f/m	25000	n.a.	h.v.h.a. h.a.d.f.	2 2	15000 scfm/400 8000 scfm/500	S	a	
3-F	6	1000 f/m	50000	n.a.	s.d.	3	n.a./160	S	a	none
29-L	10	4500 s/h	12500	n.a.	h.a.	2	n.a./200	S	a	none
9-LP	262	50000 iph	40 lb/ton	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	none
10-LP	250 16	1800 f/m 1100 f/m	n.a. n.a.	20 est. n.a.	n.a. n.a.	n.a. n.a.	n.a. n.a.	n.a. n.a.	n.a. n.a.	none none
3-MD	4**	80 s/m	1400***	n.a.	h.a.o.	4	6000 scfm/325-425	S	a	d.u.

*7 litho, 9 coaters

**2 litho, 2 coaters

***7200 gallons solvent

TABLE 17

FIELD VISIT DATA

Georgia - Tennessee - Florida

PROCESS/EQUIPMENT			MATERIALS CONSUMED		DRYING EQUIPMENT			STACK GEOMETRY		APC EQUIPMENT[d]
Code[a]	Plate Cyl's.	Printing Speed[b]	Ink lb/mo	Paper ton/mo	Type[c]	No.	Air Flow/°F Per Press Unit	Single/ Mnfld.	Suitable Sampling[e]	
21-L	14	800 f/m	30000	2850	o.f. h.a.d.f.	2 1	n.a./500 n.a./500**	S	a	none
22-L	2	600 f/m	2000	100	n.a.	n.a.	n.a.	n.a.	n.a.	none
23-L	22	800 f/m	10600	n.a.	h.v.h.a. & d.f. h.a.d.f. h.v.h.a	1 2 1	1500 cfm*/ 500**	S	a	none
7-LP	43	1450 f/m	133000	n.a.	h.a.d.f. h.v.h.a.	2 2	1500 cfm/550	S	a	none
24-L	34	900 f/m	4500	1250	h.a.d.f. d.f.	2 1	n.a./350	S	a	none
1-F	28	850 f/m	90000	1600	h.v.h.a. h.a. s.	2 1 1	n.a./325 n.a./375 n.a./200	S	a	none
25-L	52	550 f/m	50000	850	h.v.h.a. & d.f. h.a.d.f.	2 3	n.a./600**	S	g	none

*per web
**recycle temp.

TABLE 18

FIELD VISIT DATA

Illinois and Wisconsin

PROCESS/EQUIPMENT			MATERIALS CONSUMED		DRYING EQUIPMENT			STACK GEOMETRY		APC EQUIPMENT[d]
Code[a]	Plate Cyl's.	Printing Speed[b]	Ink lb/mo	Paper ton/mo	Type[c]	No.	Air Flow/°F Per Press Unit	Single/ Mnfld.	Suitable Sampling[e]	
3-L	34	300 f/m	50000	n.a.	h.a.d.f.	4	2600 scfm/325	S	a	4-c.c.
4-L	18	800-1000 f/m	25000	n.a.	h.a.d.f.	4	2800 scfm/220	S	a	2-d.f.
2-LP	112	700-1600 f/m	528000	n.a.	h.a.d.f.	16	5-12,000 scfm/ 300-375	S	a	none
5-L	50	1000 f/m	9300	n.a.	h.a.d.f.	5	3500-4000 scfm 300-325	S	a	none
6-L	6	750 f/m	10000	450 est.	h.a.d.f.	2	n.a./500-700	S	a	none
7-L	36	600-1000 f/m	n.a.	1500	h.a.d.f.	6	3000 scfm/ 220-300	S	a	2-d.f. 3-c.c.
8-L	40	800 f/m	25000	n.a.	h.a.d.f.	5	n.a.	S	a	none
9-L	24	400-800 f/m	4900	n.a.	h.a.d.f.	3	n.a.	M	d	d.f.
4-G	116	800-1500 f/m	n.a.	n.a.	h.a.s.h.	116	2500 cfm/140	M	d	none
5-G	42	n.a.	n.a.	n.a.	h.a.	n.a.	n.a.	M	d	none
8-LP	72	1700 f/m	n.a.	n.a.	r.c./h.a.	n.a.	n.a./350	M	d	c.c.& d.f.

Table 18 cont'd.
Illinois and Wisconsin

PROCESS/EQUIPMENT			MATERIALS CONSUMED		DRYING EQUIPMENT			STACK GEOMETRY		APC EQUIPMENT[d]
Code[a]	Plate Cyl's.	Printing Speed[b]	Ink lb/mo	Paper ton/mo	Type[c]	No.	Air Flow/°F Per Press Unit	Single/ Mnfld.	Suitable Sampling[e]	
27-L	8	1200 f/m	18000	n.a.	h.a.d.f.	1	n.a./250	S	a	none
26-L	8	800-1000 f/m	16000	n.a.	h.a. h.a.d.f.	1 2	4200 cfm/370 6000 cfm/370	S	a	none
6-G	5	400 f/m	2000	n.a.	h.a.s.h.	1	5000 cfm/200	S	a	none
9-MD	2*	80 s/m	15000	n.a.	h.a.s.h.	1	4-5000 cfm/350	S	a	none
7-G	41	400 iph	104000	n.a.	h.a.	6	15000 cfm/150	S	a	none
2-F	27	650 iph	80000	n.a.	h.a.	5	4000 cfm/150	S	a	none

*2 coaters

TABLE 19

FIELD VISIT DATA

California

PROCESS/EQUIPMENT			MATERIAL CONSUMED		DRYING EQUIPMENT			STACK GEOMETRY		APC EQUIPMENT[d]
Code[a]	Plate Cyl's.	Printing Speed[b]	Ink lb/mo	Paper ton/mo	Type[c]	No.	Air Flow/°F Per Press Unit	Single/ Mnfld.	Suitable Sampling[e]	
11-L	16	1200 f/m	33300	n.a.	h.a.d.f. h.a.d.f.	1 2	2200 cfm/400 7000 scfm/350	S	g	d.f. d.f.p.h.r.
4-MD	13*	80-100 s/m	12000	n.a.	h.a.o. h.a.o.	6 4	5-10000 scfm/ 325-415 5-10000 scfm/ 325-415	S	d	6-d.f.h.r. 3-c.c.
12-L	8	17000 iph	830	350 est.	h.a.d.f.	2	700 scfm/300	S	g	none
3-LP	6	1000 iph	167	5 est	none		none	none		none
2-G	20	1200-2000 f/m	n.a.	200 est.	h.a.s.h.	2	2700 cfm/90**	S	g	s.r.
4-LP	4	1100-1200 f/m	n.a.	15 est.	none		none	none		none
13-L	18	670 f/m	13000	150 est.	h.a.d.f.	2	5200 cfm/250	S	g	none
5-LP	24	1200-1500 f/m	75000	175 est.	none		none	none		none
14-L	8	1100-1200 f/m	1500	25 est.						

*9 coaters

** per unit

Table 19 cont'd.
California

PROCESS/EQUIPMENT			MATERIAL CONSUMED		DRYING EQUIPMENT			STACK GEOMETRY		APC EQUIPMENT[d]
Code[a]	Plate Cyl's.	Printing Speed[b]	Ink lb/mo	Paper ton/mo	Type[c]	No.	Air Flow/°F Per Press Unit	Single/ Mnfld.	Suitable Sampling[e]	
6-MD	2	80 s./m	n.a.	n.a.	h.a.	1	n.a./430	S	a	none
	6*	80 s./m	n.a.	n.a.	h.a.	1	11500 scfm/430	M	d	d.f.h.r.
	1	100 s/m	n.a.	n.a.	h.a.	1	10000 scfm/430	S	a	d.f.h.r.
	1	100 s/m	n.a.	n.a.	h.a.	1	6500 scfm/335	S	a	d.f.h.r.
	1	n.a.	n.a.	n.a.	h.a.	1	n.a./430	S	a	none
15-L	8	18000 iph	3000	150 est.	h.a.d.f.	1	4000 cfm/600	S	a	none
	10	18000 iph	4000	150 est.	h.a.d.f.	4	3000 cfm/550	M	a	none
	16	24000 iph	6000	200 est.	h.a.d.f.	4	3000 cfm/550	M	a	none
17-L	10	18000 iph	5500	80 est.	none		none	none		none
	8	28000 iph	500	75 est.	o.f.	1	3000 cfm/400	S	a	none
	20	32000 iph	1100	50 est.	none		none	none		none
18-L	8	20000 iph	6500	50 est.	h.a.d.f.	1	1800 cfm/230	S	a	none
	8	30000 iph	4000	50 est.	h.a.	1	1400 cfm/300	S	a	none

*2 coaters

Table 19 cont'd.
California

PROCESS/EQUIPMENT			MATERIAL CONSUMED		DRYING EQUIPMENT			STACK GEOMETRY		APC EQUIPMENT[d]
Code[a]	Plate Cyl's.	Printing Speed[b]	Ink lb/mo	Paper ton/mo	Type[c]	No.	Air Flow/°F Per Press Unit	Single/ Mnfld.	Suitable Sampling[e]	
19-L	10	19000 iph	9000	75 est.	h.a.d.f.	1	7400 cfm/400	S	a	none
	8	16000 iph	9000	75 est.	h.a.d.f.		3500 cfm/400	S	a	none
7-MD	1	50 s/m	6000	n.a.	h.a.		3000 cfm/225	S	d	s.ch.
3-G	1	150 f/m	75	n.a.	none		none	none		none
8-MD	1	50 s/m	n.a.	n.a.	h.a.	1	2500 cfm/150	S	a	none
16-L	8	21000 iph	6250	150 est.	o.f.	1	3000 cfm/350	S	a	none

TABLE 20

CLASSIFICATION OF POLLUTANTS*

Major Class of Pollutant	Division of Pollutant	Typical Members of Subdivision
Organic Gases	Hydrocarbons	Aliphatics, including isoparaffins and cyclo-paraffins Olefins Aromatics
	Oxygenated Organics	Aldehydes, Alcohols, Ketones, Esters, Acids
	Other Organics	Chlorinated hydrocarbons Heterocyclics
Inorganic Gases	**Oxides of Nitrogen	Nitrogen dioxide, nitrogen oxide
	**Oxides of Sulfur	Sulfur dioxide, sulfur trioxide
	Oxides of Carbon	Carbon monoxide, carbon dioxide
	Water Vapor	
	**Other Inorganics	Hydrogen sulfide, ammonia, etc.
Particulates	**Solid Particulates	Dust, smoke, fume
	**Liquid Particulates	Mist, spray, fog

*Modification of Reference 33.

**Pollutant expected to be minimal throughout the industry.

TABLE 21

SAMPLING METHODS FOR EFFLUENTS FROM PRINTING & METAL DECORATING PLANTS

Method	Period (min)	Probe	Trap	Sampler	Meter	Regulator	Pump
L.A. APCD	20	s.s. (tape-heated)	s.s., coiled U dry ice-Methyl Cellosolve	2-l flask glass evac.	vac. gage, monitor rate	needle valve (trap - flask)	vac.
Cal-Colonial	1 (125 ml)	s.s. (1/8" x 12") w/fittings	dry ice	gas bottle (125 ml)	vac. gage monitor rate	needle valve	vac.
Poly-technic	30	s.s. (tape-heated)	scrubber (particulates), ice in series	4-250 ml scrubbers in CCl_4	dry gas meter	flow meter & vac. gage	vac.
Phoenix Chem. Lab.	10-30	"	none	100 ml tube (Teflon stop-cocks)	none	flow meter	vac.
Illinois Inst. Tech.	20-45	"	U-tube, dry ice	Apiezon L-Teflon powder (fluidized bed)	vac. gage	flow meter (0.5-0.75 l/sec)	air blower (reversible)
Truesdail	20	"	double U, dry ice-isopropanol	gas bottle (std. vol)	vac. gage	needle valve	vac.
S.F.B.A. APCD	15	s.s. or glass	silica gel (2-cartridges)	s.s. tank (5 gal)	vac. gage	flow meter 0.5 cfm	vac.

s.s.- stainless steel

TABLE 22

NUMBER OF EQUAL AREAS FOR VELOCITY MEASUREMENT IN CIRCULAR STACKS (34)

Stack diameter feet	Number of equal areas
1 or less	2
1-2	3
2-4	4

TABLE 23

NUMBER OF EQUAL AREAS FOR VELOCITY MEASUREMENT IN RECTANGULAR AND SQUARE STACKS (34)

Cross-Sectional area ft^2	Number of test points
less than 2	4
2 through 12	6-25

TABLE 24

PERCENT OF FLUE DIAMETER FROM CIRCUMFERENCE TO TEST POINT(34)

Point No.	Number of Areas				
	2	3	4	5	6
1	6.7	4.4	3.3	2.5	2.1
2	25.0	14.7	10.5	8.2	6.7
3	75.0	29.5	19.4	14.6	11.8
4	93.3	70.5	32.3	22.6	17.7
5		85.3	67.7	34.2	25.0
6		95.6	80.6	65.8	35.5
7			89.5	77.4	64.5
8			96.7	85.4	75.0
9				91.8	82.3
10				97.5	88.2
11					93.3
12					97.9

TABLE 25

INSTRUMENTAL METHODS OF ANALYSIS CURRENTLY IN USE THROUGHOUT THE GRAPHIC ARTS INDUSTRY

	Method Used By	Primary Instrument(s)	Auxiliaries
1.	Los Angeles APCD	Gas chromatograph w/non-dispersive infrared analyzer	
2.	Honeywell, Inc.	Similar to L.A. APCD	
3.	Truesdail Labs.	Similar to L.A. APCD	
4.	Cal-Colonial Chemsolve	Gas chromatograph w/flame ionization detector cell	
5.	Continental Can Co., Inc.	Total hydrocarbon analyzer	NDIR instrument
6.	Polytechnic, Inc.	IR spectrophotometer	
7.	Hirt Combustion Engineers	Total combustibles analyzer	Ultra-violet analyzer
8.	IIT Research Institute	Gas chromatograph w/sample injection system	
9.	San Francisco Bay Area APCD	Gas chromatograph w/flame ionization and thermal conductivity cells	IR Spectrophotometer
10.	Ambassador College Press	Gas chromatograph	Hot-wire detector Mass integral detector

TABLE 27

RANGE OF CONCENTRATION AND FLOW RATE
DATA FOR EQUIPMENT TESTED UNDER RULE 66 (45)

Process	Gas Flow Rate (scfm)	Emissions (ppm as equiv. CO_2) (a)					
		Uncontrolled (a)			Controlled (b)		
		CO_2	CO	ORGANICS	CO_2	CO	ORGANICS
Paint Bake Ovens	300–4,000	400 15,000	10 350	150 2,000	20,000 50,000	0 150	15 200
Lithograph (Can) Ovens	1,100–3,500	3,000 10,000	50 300	2,000 10,000	20,000 40,000	100 300	20 500
Web Printing Presses	1,500–3,500	2,000 8,000	30 120	300 1,500	NO DATA AVAILABLE		

a) Emissions to atmosphere, or to inlet of afterburner control unit
b) Emissions from afterburners, operating at efficiencies of 90 percent or greater
c) Paired concentrations represent low to high extremes found

TABLE 28

RELIEF PRINTING

A. LETTERPRESS

1. Characteristic Points

Widely diversified process having equipment for short, medium and extremely long runs. Uses a roller inking system with a viscous, paste ink. Capable of press speeds up to 1500 ft/min. Applicable to sheet and web-fed printing.

2. Printing Stocks

Can print on many different grades of paper and on paper boards. Uses coated and uncoated paper.

3. Printing Inks Used

Uses a wide range of inks. Ink properties will depend on press speed paper and type of job. For slower presses a more viscous ink is used than for faster ones. Most inks dry by oxidation and polymerization. Vehicles used are slow-drying alkyds or vegetable oil (e.g., linseed oil) derivatives. Heatset inks for high speed web printing contain resins in hydrocarbon solvents of which the latter are evaporated in oven dryers.

4. Air Pollution Problem

During oxidative drying, chemical changes occur that can result in odorous products; however, concentrations are expected to be minimal. Even with driers added, initial drying takes two or three hours while the process actually continues for days.

Potential air pollution products are encountered in the dryer exhaust from heatset ink drying on web-fed presses.

5. Partial Solutions to Problems

Drying oil vehicles can be modified extensively, but the fundamental process is oxidation of the oils and cannot be altered. Odor is eliminated by the use of "moisture set" ink (other resins in glycol) which have limited applications.

Table 28 cont'd.

Catalytic or direct flame incineration is used for solvent emissions from heatset inks. New solventless thermally catalyzed heatset inks are expected to eliminate solvents and other new radiation curing processes are anticipated.

B. FLEXOGRAPHY

1. Characteristic Points

Uses a thin, low viscosity, volatile ink with one or more rollers between the ink fountain and the plate. Primarily used in packaging and also paper products. Can produce either rewound sheeted or in-line fabricated products.

2. Printing Stocks

Can print on a wide variety of papers, paper boards, metal foils, plastic films and others.

3. Printing Inks Used

Inks are low viscosity, solvent-resin systems colored either with dyes, pigments, or combinations thereof. The film-forming ingredients vary but usually are soluble in alcohol, alcohol-hydrocarbon or water.

4. Air Pollution Problems

Alcohol or water-based inks are used extensively with few pollution and odor problems. Some inks using dye-stuff colorants when permitted to come in contact with metals induce a chemical reaction and a marked odor which is offensive in products but not a pollution problem.

5. Partial Solution to Problems

Prevent dyestuff inks from coming into contact with metals by use of barrier layers, or use pigment based inks.

TABLE 29

PLANOGRAPHIC PRINTING

A. LITHOGRAPHY

1. Characteristic Points

Widely used process in the printing industry. Has equipment for short, medium and extremely long runs. Employs plates with water-receptive non-image areas and ink-receptive image areas. Uses a roller inking system with a heavy bodied ink (usually more viscous than letterpress) which is highly pigmented. In addition, a fountain solution (water, alcohol, gums and salts) also is applied to the plate. Applicable to sheet-fed and roll-fed or web presses. Direct lithography transfers the ink directly to the sheet. More popular offset lithography transfers ink from plate to blanket and from blanket to substrate.

2. Printing Stocks

Can print on an exceptionally wide range of papers, cloth, plastic and foils. Papers are smooth and in general coated. However, rough or purposely structured papers can be used for aesthetic reasons.

3. Printing Inks Used

Uses a wide range of inks corresponding to the range of printing equipment. Some inks for offset lithography dry by oxidation and polymerization. The viscosity of inks decreases as the press speed mounts; web offset printing usually employs heatset inks which dry by evaporation of solvents under the influence of heat and air currents. Vehicle used consists of oils and resins in hydrocarbon solvents which will resist mixing with water.

4. Air Pollution Problems

During oxidative drying chemical changes occur that can result in odorous products. The products constitute a nuisance odor and thus an air pollution problem. There is less latitude in materials selection because of the necessary water-repellent property.

Table 29 cont'd.

The major pollution problem is encountered with dryer effluent from web-fed presses utilizing heatset inks.

5. Partial Solution to Problem

If odor causing vehicles are removed, the ink loses important printing properties. However, inks with minimum quantities of drying oil have been developed and are in use.

Catalytic and direct flame combustion units are being used to control the pollution from heatset inks. Of note is the recent development of non-solvent "solid state" inks. One limitation is low gloss that has been obtained to date. Other radiation curing systems are being developed.

B. METAL DECORATING

1. Characteristic Points

Normally sheet-fed offset lithography is employed. Substrate is roller coated before printing with a lacquer that generally contains a vinyl resin. Following the printing, a varnish or final coating is applied with a roller coating system. Roller coatings also are applied continuously to metal rolls in separate operations.

2. Printing Stocks

Printing is performed on sheet metal surfaces mainly tin plate or aluminum.

3. Printing Inks Used

Lithographic printing inks are employed; however, the principal solvent sources are the varnishes and the coatings used by the industry. All are dried by hot air.

4. Air Pollution Problems

The printing ink varnishes are based on a wide variety of coatings, i. e., linseed, alkyds, vinyls, epoxy, that lend themselves to baked finishes. Comparatively little solvent is emitted. A variety of solvents are used in the lacquers and varnishes including hydrocarbons (xylene), ketones, and alcohols.

Table 29 cont'd.

5. Partial Solution to Problem

Because of the variety of coatings and solvents used, the present control approach is toward direct or catalytic combustion unit. Use of exempt solvents and reformulation does not reduce substantially the quantity of solvent, only the character, which in certain geographic areas, reduces photochemical smog formation and eye irritation. Regulations such as Los Angeles Rule 66 and San Francisco Regulation 3, therefore, are not universally suitable and have not been adapted in other states.

TABLE 30

INTAGLIO PRINTING

ROTOGRAVURE

1. Characteristic Points

Widely used in package printing as a web printing process capable of long production runs of publications, package materials, etc. The ink fountain is simple and the partially immersed cylinder emerges flooded with ink which is wiped off by a doctor blade. The ink is volatile and low viscosity. Press speeds are high — on the order of 2000 ft/min. The high cylinder cost limits the process to long production runs.

2. Printing Stocks

This process makes minimum demands on paper or film properties. The stock needs to be sufficiently smooth or compressible to have each cylinder cell print. Sheet-fed gravure is done on better grades of paper, i.e., coated stocks. Publication printing can be done on inexpensive papers but high grade products usually are printed on coated papers. Paper boards, tissue, metal foil, laminates, plastic films are used as stocks in package printing.

3. Printing Inks Used

Inks are of low viscosity and usually dry by solvent evaporation. Various printing stocks require differently formulated inks. Vehicles are resins dissolved in suitable solvents. New inks are now available in which the resins undergo chemical bonding during drying.

4. Air Pollution Problem

Solvent evaporation by hot air drying of the web creates potential pollution problems. Among the conventional solvents used, toluene and xylene also have appreciable odor. To some extent these solvents have been replaced with alcohol (methylated spirits) having a much milder and less objectionable odor.

Table 30 cont'd.

5. Partial Solution to Problem

Conventional solvents lend themselves to collection by solvent recovery. Care must be exercised in drying the print completely to avoid odor problems in packaging.

TABLE 31

SCREEN PRINTING

1. Characteristic Points

   Primarily a picture printing method used for displays, greeting cards, decalcomanias, signs, printed circuits, wallpaper, etc. Hand printing frequently used. Image areas consist of open screen. In non-image areas the screen pores are blocked. Prints are characterized by thick ink films and strong colors.

2. Printing Stocks

   Almost all flat surfaces are used including paperboard, plastic sheets, metal foil, sheet metal, wood, etc., and the process lends itself to irregularly shaped items.

3. Printing Inks Used

   Inks contain a wide variety of solvents varying extensively in concentration. Low solvent oleoresinous inks give thick matte appearance. High solvent fast drying lacquers are used for paperboard. Air drying or baking alkyd enamels are used for glass bottles. Clear coatings, adhesives, water colors and emulsions can also be applied.

4. Air Pollution Problem

   Fast drying lacquer inks are one serious source of pollution. Ovens used for baked coatings are another.

5. Partial Solution to Problem

   Small incinerators on drying ovens for largest operations using baking or lacquer inks.

TABLE 37

LIST OF DRYING MECHANISMS (53)

Physical	Example
1. Absorption	Newsprint inks
2. Evaporation	Heatset inks/gravure inks
3. Precipitation	Moisture-set inks Quick-set inks Wax-set inks
4. Phase change	Cold-set inks
Chemical	
1. Oxidation	Sheet-fed litho inks
2. Polymerization	Metal decorating inks
3. Cross-linking	Metal decorating inks

TABLE 38

LIST OF DRYING TECHNIQUES (53)

Thermal

1. Convection
2. Conduction
3. Radiation (electromagnetic)
    a. Infrared (.75 - 16.0 microns)

Physical

1. Forced air (oxidation or evaporation)
2. Application of moisture
3. Precatalyzed (paper or fountain solution)

Chemical

1. 2-component catalyzed (ink)
2. Post-catalyzed (spray, vapor, etc.)
3. Encapsulation catalyzed
4. Radiation
    a. Ultraviolet (0.01 - 0.4 microns)
    b. Microwave (16.0 - 10,000 microns)
    c. Radiation (electron-beam)
5. Electrical discharge

Other

1. Electrical magnetic field

TABLE 39

SUMMARY OF CONTROLS IMPOSED BY RULE 66 AND REGULATION 3

1. Emission of ALL solvents which are heated is restricted.

*Rule 66	**Regulation 3
85% or 15 lb/day	85% or 10 lb/day

2. Emission of ALL photochemically reactive solvents is restricted.

Rule 66	Regulation 3
85% or 40 lb/day	85% or 20 lb/day

3. A photochemically reactive solvent is any solvent which contains more than:

Rule 66	Regulation 3
Olefins 5%	8%
Aromatics C_8 and above (except ethyl benzene) 8%	8% - Disubstituted aromatics only
Branched chain ketones 20%	No restriction
Ethylbenzene, Toluene 20%	20%

Or more than 20% in combination

*Applies to all printing processes where solvents are used.
**Places restrictions on rotogravure printing only.

TABLE 40

TYPICAL POISONS, SUPPRESSANTS AND FOULING AGENTS FOR PLATINUM-FAMILY CATALYSTS (62)

Type	Example
Poisons	Heavy Metals - Phosphates - Arsenic
Suppressants	Halogens (both as elements and in compounds) Sulfur compounds
Fouling Agent	Inorganic particulate Alumina and silica dusts Iron oxides Silicones

TABLE 44

COMPARATIVE COSTS FOR CATALYTIC AND FLAME AFTERBURNER (71)

	Operating Condition			Unit Costs $/hr per 1000 cfm.		
Case No.	Extent of Waste Heat Recovered	Calorific Value of Odor Source Gas	Item of Cost	Catalytic Method	Direct-Flame Method	Cost Ratio Flame/Cat.
1	None	Nil	Fixed charges	$0.15	$0.10	
			Burner	0.51	1.06	
			Maintenance	0.09	0.06	
			Labor	0.03	0.03	
			Total	$0.78	$1.25	1.60
2	None	1/4 LFL*	Fixed charges	$0.15	$0.10	
			Burner fuel	0.03	0.58	
			Maintenance	0.09	0.06	
			Labor	0.03	0.03	
			Total	$0.30	$0.77	2.45
3.	1/2 of Input	Nil	Fixed charges	$0.19	0.17	
			Burner	0.27	0.58	
			Maintenance	0.11	0.10	
			Labor	0.03	0.03	
			Total	$0.60	$0.88	1.33
4	1/2 of Input	1/4 LFL*	Fixed charges	$0.19	$0.17	
			Burner fuel	(-0.20)	0.10	
			Maintenance	0.11	0.10	
			Labor	0.03	0.03	
			Total	$0.13	$0.40	3.10

*Lower Flammability Limit

APPENDIX D

Questionnaire

B.O.B. 85-S69027
Expires April 30, 1970

GRAPHIC ARTS TECHNICAL FOUNDATION, INC.

SURVEY OF SOLVENTS AND INKS USED IN THE PRINTING INDUSTRY DURING 1968*

If for some reason a question cannot be answered please write "Not Available" in place of the information requested. This survey is CONFIDENTIAL and individual sources of information will not be identified in any way. This page will be separated from the balance of the questionnaire upon receipt.

The data will be analyzed according to area and for this reason it is necessary that the location of the plant is known. We are asking for the identity of the person supplying the information in case it becomes necessary to get further clarification of the information supplied.

1. Use separate questionnaires for each individual printing establishment in your company. If both metal decorating and general printing are done at one location fill out two questionnaires, (i.e., one for metal decorating and one for general printing). General printing covers printing by lithography, letterpress, gravure, flexography, and screen on any substrate except metal.

Plant Name .... Date ....

Address .... Phone ....

City .... County .... State .... Zip Code ....

Location ☐ Commercial Area ☐ Industrial Area ☐ Residential Area ☐ Other (describe) ....

Filled out by .... Title ....

Identification No. ☐ (For GATF use only)

(An identification Number will be assigned to each questionnaire when returned to GATF. This sheet will then be removed from the rest of the questionnaire, thus providing anonymity of respondent.)

---

*Sponsored by National Air Pollution Control Administration of the U.S. Department of Health, Education and Welfare. Contract CPA 22-69-72.

NAPCA Form #HQ34(7-69)

Identification No. ☐

Check appropriate box:

☐ General Printing

(Lithography, letterpress, gravure, flexography, screen on any substrate except metal.)

☐ Metal Decorating

(Include only the printing and/or varnishing operations.)

2. List TOTAL lbs. of ink used during 1968 (include varnishes).

Purchased: All inks manufactured outside your plant and meant to be used as purchased. **Made In Plant:** Inks blended or manufactured within your plant using pigments and solvents. Include solvents used in these inks under Item 3. **Heatset:** All inks in which the main drying mechanism is solvent release and the inks are dried in a drying oven. **Other:** All inks which do not qualify as "Heatset".

	Purchased		Made in Plant	
Process	Heatset	Other	Heatset	Other
Lithography				
Letterpress				
Gravure				
Flexography				
Screen				

3. List solvents according to either common chemical name or trade name. If additional space is needed, use reverse side. Include solvents used for "Made In Plant" inks listed under item 2.

Total gallons of solvents added to inks or used in your printing operation during 1968. Include solvents used for wash-ups, platemaking, etc.

Solvent (Name)	Gallons	Use	Percent recovered

☐ Check here if more solvents are listed on back of page.

4. Describe each oven/dryer-equipped press in your plant.

Process: Litho, letterpress, etc. **Plate Cylinders:** List the number of plate cylinders in the press. **Size:** Show press cut-off size (L) and web width (W). **Speed:** Average net production in impressions per hour. **Per cent of time in operation:** Show actual operating time as a percentage of total production time possible for a seven day around-the-clock operation (7x24 or 168 hours). (Use back of page if more space is needed.)

Press	Process	Plate Cylinders	Size (LxW)	Speed IPH	% of Time in Operation
1					
2					
3					
4					
5					
6					
7					
8					

☐ Check here if more presses are listed on back of page.

5. Describe drying equipment on presses listed in Item 4. Dryer 1 for press 1, etc.

Heating Medium: Steam, Hot Air, Direct Flame, etc.
Energy Source: Gas, Electricity, Oil, etc.
(Use back of page if more space is needed.)

Press	Manufacturer/ Model	Heating Medium	Energy Source	Consumption/hr.	Exhaust Rate cfpm	Exhaust Temperature
1						
2						
3						
4						
5						
6						
7						
8						

☐ Check here if more dryers are listed on back of page.

6. Other pertinent activities (bindery, film processing, typecasting, platemaking, etc.) which cause emissions to the atmosphere. Describe Annual Volume of Product in terms most convenient. For example, typecasting may be expressed as lines cast, pounds of metal melted, etc.

Activity	Annual Volume of Product

7. Air Pollution Control Equipment (include solvent recovery systems).

In describing any air pollution control equipment please answer as many as possible of the following questions: **(a)** Type, manufacturer and model; **(b)** Air flow rates and temperatures; **(c)** Fuel and power consumption; **(d)** Method of performance validation; **(e)** Manufacturer's performance specifications. Information regarding expenditures for such equipment would also be welcomed. (Use other side of page for additional information or comments on equipment.)

(a)
(b)
(c)
(d)
(e)

☐ **Check here if back of page is used.**

8. Do you have any emissions data? Describe data as to type, quality, etc. How long have you been collecting such data? Will such data subsequently be available to GATF?

9. Comments.

Please include any information which you feel is pertinent and is not already covered. Your comments on this questionnaire and survey will be appreciated. You may use the other side of page or attach a separate sheet.

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15. Supplementary Notes

16. Abstracts A multi-faceted study was conducted to determine the nature of emission problems in the graphic arts and metal decorating industries. Beginning with acquiring an initial perspective of the industry's involvement and its problems, the study progressed through several intermediate steps. By means of field visits and a survey of solvent and ink use, the industry's actual and potential problems were delineated and methods used for solving these were reviewed. Available sampling techniques were critically reviewed with the intention of selecting a procedure capable of providing all data necessary to evaluate accurately a given source. An industry sampling plan was developed that will measure and attempt to characterize the emissions, according to the process, type of ink coating and substrate used. Analytical procedures requisite to the chemical evaluation of effluents and sampling technique employed were examined and reviewed. Although numerous and sophisticated techniques exist for the precise identification of gaseous compounds the less complex method of total hydrocarbon analysis would suffice for certain segments of the industry. Solvent flow charts for the basic printing processes and modifications thereof were utilized (over)

17. Key Words and Document Analysis. (a). Descriptors

Air pollution
Exhaust emissions
Air pollution control equipment
Graphic arts
Industrial wastes
Solvents
Printing inks
Surveys
Sampling
Hydrocarbons
Flow charts
Material balance
Heat balance
Decorative coatings
Letterpress printing
Lithography
Gravure printing
Flexography
Gas analysis
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Revisions
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17b. Identifiers/Open-Ended Terms

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16. Abstracts

to indicate the process variables in terms of inputs and outputs. Solvent consumption data and assumed levels of operation variables were used to calculate emission rates for several processes. Significant emissions can be expected from web printing (letterpress and lithography using heatset inks), metal decorating, gravure and flexography. Control techniques were reviewed and presented in the light of information gained from field visits to equipment manufacturers and from those companies employing air pollution control equipment. There are three general approaches to the problem of controlling gaseous emissions from the printing and metal decorating industries: the first, the use of air pollution control equipment, the second, a change of process materials and the third is process modification. Immediate requirement for control is being satisfied with control equipment, thermal and catalytic incineration, adsorption, scrubbing and other measures. All were considered from both a technological and economic review. Changes in process material (e.g., solventless or low-solvent inks) were reviewed. Developments in radiative drying were also discussed.